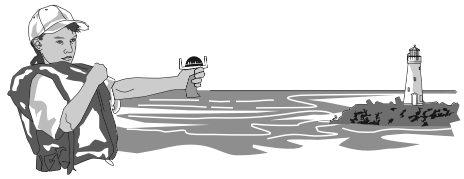
O'Neill
Sea Odyssey

Investigations in a
National Marine
Sanctuary



O'Neill Sea Odyssey is a highly successful example of how one organization uses local marine natural resources, habitats, and organisms as educational tools to assist thousands of students each year to make connections between the oceans and their lives. O'Neill Sea Odyssey: Investigations in a National Marine Sanctuary describes this field and classroom-based program designed for students in grades four through six. Using a successful program established in the Monterey National Marine Sanctuary by O'Neill Sea Odyssey, a non-profit organization, this book contains exciting hands-on activities conducted either on a vessel or a waterside dock or pier, or in a classroom. Students rotate through six different stations on board or dockside and in the classroom, and participate in active investigations on navigation, marine habitats, marine ecology, and conservation. Topics and themes follow the National Science Content Standards for grades four through six. This publication was made possible through a Toyota Foundation Tapestry Grant to O'Neill Sea Odyssey.

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This book is the product of a partnership between O' Neill Sea Odyssey and The National Oceanic and Atmospheric Administration (NOAA) under a grant from the Toyota USA Foundation. NOAA, in the United States Department of Commerce (USDOC), manages the Monterey Bay National Marine Sanctuary (MBNMS). One of MBNMS' most important educational goals is communication and collaboration with organizations that share similar educational goals in order to strengthen the effectiveness of MBNMS educational efforts.

O' Neill Sea Odyssey and NOAA formed their partnership with funding from The Toyota USA Foundation to produce and distribute a nationally applicable curriculum to provide teachers and environmental educators with a free educational resource. This hands-on curriculum is designed to allow users across the nation to adapt lessons to their own ecosystem, from tropical coral reefs to cold-water kelp forests. Through the national distribution and implementation of this curriculum O' Neill Sea Odyssey and NOAA hope to contribute to public awareness of the National Marine Sanctuary System.

O' Neill Sea Odyssey was founded in 1996 by wetsuit innovator and surfer Jack O'Neill. Through Jack's vision, a living classroom was created on board a 65-foot catamaran sailing the Monterey Bay National Marine Sanctuary. Students receive hands-on lessons about the marine habitat and the importance of the relationship between the living sea and the environment. The program is conducted on board the catamaran with follow-up lessons at the shore-side Education Center at the Santa Cruz Harbor. It is free of charge, but students earn their way into the program by designing and performing a project to benefit their community.

The curriculum is taught in a stimulating and intimate learning environment, which provides a learning experience that lasts a lifetime. "The objective of Sea Odyssey is to teach kids about our living ocean and emphasize that we must take care of it," says Jack O' Neill. "We take a lot of underprivileged kids and it opens a lot of doors for them. I've had kids tell me they were going to be this or that but then decide they're going to be a marine biologist."

O' Neill Sea Odyssey has had a far-reaching and beneficial effect on our local communities. Since its inception, it has served more than 20,000 students. Not only has the interest of these students been stimulated in marine science and environmental conservation, they have also contributed directly to their community through their environmental community service projects.

We hope this guide provides a useful tool for educators, schools, and organizations to provide a truly rich, hands-on learning experience for today's youth in environmental stewardship, ocean ecology, marine science, geography and community service.

Dan Haifley
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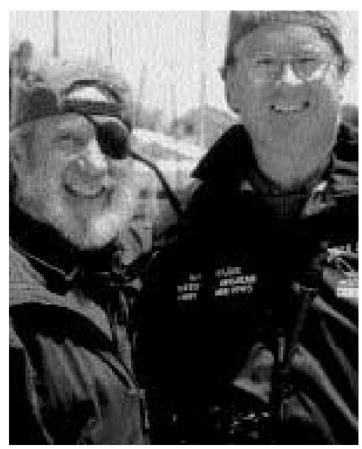
Introduction

One of the most lasting impacts we can have on children is to provide them the opportunity to experience first hand the sights, sounds, and smells of the ocean. Indelible sensory impressions, not available through science textbooks, drive home the message the oceans are something worth taking care of. Watching a bird dive for a fish, a sea lion lounging on a buoy, an otter cracking a crab on its stomach—it is simply amazing how accessible these sights can be once you get students out of the classroom. The O'Neill Sea Odyssey program opens children's eyes to aspects of nature many never considered before. Whether these children become marine biologists, mathematicians, or musicians, they will integrate their understandings and experiences of the oceans in all that they do.

This guide provides a detailed description of how one program designed activities to help students celebrate and learn about the natural resources of the Monterey Bay National Marine Sanctuary. It provides an excellent model of how to create a successful program in a marine sanctuary, and tips for how to "localize" the activities to suit different habitats and natural features. As a special feature, coral reef activities are provided for those sanctuaries that contain reef habitats.

The O'Neill Sea Odyssey program consists of on board and shoreside classroom stations. This approach allows students to have exciting boat adventures, and classroom time to reflect and connect their experiences to larger science concepts. If weather conditions are too rough to sail outside the harbor, the on board portion is conducted on the docked vessel. The program provides a stimulating environment in which students learn teamwork, contemplate the natural beauty and resources of the sanctuary, discover practical applications for math and ocean sciences, and learn what it means to be an ocean steward. Topics and themes from the National Science Content Standards are incorporated into activities conducted at each station where appropriate (Appendix A). For instructors who wish to conduct this program in a sanctuary where a vessel that will accommodate up to 40 students and chaperones is unavailable, modifications are presented in the activity so the on board element may be conducted off a bridge, dock, or wharf.



Founder Jack O' Neill with U.S. Representative Sam Farr (D-Carmel), one of many supporters of O' Neill Sea Odyssey.

Student-led community service projects are a critical component part of the O'Neill Sea Odyssey program. To become eligible for the program, students design and complete a community service project. Applications are accepted for cruises March through August and October through December, and teachers submit a description of their community service project as part of the application process.

The community service projects encompass a wide range of activities, including beach or shoreline clean up, native plant restoration, homeless gardens, community education programs, school-wide recycling programs, adopt-a-family, adopt-a-creek, or fund raising activities for non-profit organizations such as native animal rescue. The project can be done at any time during the school year. Teachers complete the evaluation form and submit it on-line, or write a letter with the date the project was completed and the outcome of the project. Sea Odyssey staff follow up with each teacher or group leader to ensure they have completed the project. A side benefit of the community service requirement for eligibility is that students earn a sense of pride and accomplishment and experience the benefits of volunteerism, a pattern that may be repeated throughout their lifetime.

Teachers mail in their application and receive a trip confirmation flyer with pre-trip information and teacher login password. As they enter the teacher login section of the O'Neill Sea Odyssey web site (www.oneillseaodyssey.org/teachers) they access a teacher packet with additional resources. Some teachers use these activities, web sites, and books to create a complete oceanography curriculum for their class, while others use the materials to familiarize students with vocabulary they will hear during the shipboard program. Other groups, such as summer camps and state parks groups, use the teacher packet as time filler on the bus trip to Santa Cruz, or as a quiet afternoon activity while at camp. The teacher packet is also available in Spanish.

Once the group arrives at the harbor, they are greeted by three instructors and the vessel's captain. Student groups rotate first through three stations on board, then three stations in the shoreside classroom. The on board and classroom stations are marine biology, ecology, and navigation. The marine ecology stations are developed for either kelp forest ecology or coral reef ecology. For sanctuaries lacking either kelp forests or coral reefs, develop your own marine ecology stations based on a habitat or feature characteristic of your sanctuary.

Each group of students (normally around 32 students and 8 adults) is split into three sub-groups and guided to the ship. Upon boarding the vessel, students are given a safety talk and assist the crew in hoisting the main sail. During twenty-minute rotations, the ecology station meets on the bow of the boat for wildlife viewing and students participate in a teacher led discussion on food webs and ocean ecology with visuals and hands on materials. The marine biology station meets on the port stern to conduct a plankton tow and discuss marine food webs. The navigation station meets inside the cabin to allow the students to view the radar and Global Positioning System (GPS) electronics, then proceeds to the main deck for taking compass bearings on landmarks or buoys.

The shoreside education center has separate areas for each of the three learning stations. Each station has seating for 15 seats to provide adequate space for teachers and parent chaperones to join the learning circle. The marine biology station is equipped with seating for the students, a small lab table, and a microscope connected to a television monitor. The ecology station requires seating for students and either an outdoor space or an easily cleaned indoor wet space. In the navigation station, students are seated around a table large enough to hold a navigational chart, parallel rulers, and a navigational data sheet.

Students become part of the crew as they hoist the mainsail on board the O' Neill catamaran.

Learning Station Overview

The O'Neill Sea Odyssey program is designed to work in a three-hour time period based on a three station educational format; three stations at sea and three stations shore side. Instructors separate the students into three groups initially, and each group remains together for the entire three-hour period, rotating between stations. Students spend 20 minutes at each station.

On Board Stations

Station 1: Navigation

Instructors explain electronic technology for navigation, triangulation, line-of-sight, use of magnetic hand-held compasses, and other elements of navigation. Students use hand-held compasses to take three bearings on local landmarks or buoys. This information is recorded on a datasheet along with readings of wind speed, temperature, water color, and depth as recorded by ship's instruments. Where possible, students participate in hoisting the mainsail. Modifications are included for a dockside activity station with no electronic navigation equipment.

Station 2: Marine Biology

The instructor describes life cycles of plankton, their role in the food web, and the unique chemical and physical balance that helps maintain life in the sea. Students participate in a plankton tow and the specimen is taken back to the classroom for further examination under a microscope. A water sample is collected and taken back to the classroom to test pH with a pH meter and salinity with a refractometer.

Station 3: Ecology—Kelp Forests

The instructor discusses selected characteristics of the marine environment, marine life, and habitats and leads a discussion that includes the kelp forest, marine mammals, human influence on our marine habitat and related ecosystems, threats to the bay, and ideas for conservation and preservation. Visual aids are used to emphasize concepts.

Station 4: Ecology—Coral Reefs

The instructor reviews with students what they know about coral reefs; the coral reef habitat, importance of coral reefs, how they are formed, what they need to survive, and current threats to coral reef health. They conduct a hands-on activity to determine how much of a coral reef is alive. The instructor describes what marine protected areas are, how they can promote coral reef health, and students hypothesize how large of an area needs to be protected to insure the health of a "typical" coral reef.

*Note: **either** station 3 or 4 is conducted.*

Shoreside Stations

Station 5: Navigation

Students plot the bearings taken on the boat onto a navigational chart and triangulate their position. The instructor describes how to read and decipher the signs, symbols, and measurements on navigational charts. Students use navigational tools such as parallel rulers, a globe, and the compass rose. The instructor discusses latitude, longitude, and basic geometry as it relates to triangulation and other elements of navigation.

Station 6: Marine Biology

Using samples from the plankton tow taken on the boat, the instructor shows how to prepare a microscope slide for viewing. The slide is viewed through a microscope connected to a large-screen monitor. Instructor leads a discussion on the different types of plankton collected. Students receive plankton identification cards, identify species on the monitor, and play a food web game.

Station 7: Ecology—Kelp Forests

The instructor provides an overview of the water cycle and local watersheds, and leads a whole group discussion on storm drains and how they relate to ocean pollution. Students use a watershed model to demonstrate point source and non-point source pollution. Students brainstorm solutions to land-based environmental problems that affect the oceans, including landfill and stream diversion; organic farming; methods of reducing waste through reduction, reuse, and recycle; and alternate forms of transportation and energy.

Station 8: Ecology—Coral Reefs

This station description contains more background information for the instructor. As students can't readily see coral reef life from the surface, they will need to use their imaginations, based on an understanding of the geology, ecology, and biology of coral reefs, to develop the sense of knowing what coral reefs are about. The station contains two activities: a quick coral reef health assessment activity, and the watershed activity from Station 7.

Pre-visit activities and follow up information applicable to Monterey Bay National Marine Sanctuary, including the data taken during the program, are available through the Sea Odyssey web site (http://www.oneillseaodyssey.org)

Welcome to O'Neill Sea Odyssey

When students first arrive is the perfect time to introduce them to a new way of thinking about education and learning. They will be using all of their senses—including balance, which throws some students—in this dynamic learning environment. Best to prepare them for the ride. Depending upon time constraints, include as much of the information below in your welcome, accommodating the text to best reflect the natural resources of your sanctuary. Discuss what a sanctuary is, and what special features were behind why your area was designated a national marine sanctuary.

Today we venture out into the largest habitat on Earth—we'll see a lot of life, but what we see on the surface is a tiny slice of what's there. Most life in the sea lives underwater, where sea lions and seals chase teeming schools of fish, killer whales stalk migrating gray whale mothers and their calves, coral reefs spawn and release clouds of eggs and sperm, majestic forests of kelp plants sway as tiny crabs and invertebrates scatter over undulating fronds, and fish hide in rocky crevasses to escape predators.

Unless you put on scuba gear or climb into a submarine, these alien worlds are inaccessible to landlubbers, and can be easy to overlook. In fact, for many years we've taken for granted the oceans are an indestructible resource that will continue to support us no matter how we treat them. We're learning differently now, as fisheries decline and coral reefs disappear. We depend upon the oceans for food, recreation, and commerce, and it is important to understand how they work. Every living thing on Earth exists for a purpose, some that we don't even know about yet. We need to support natural systems so they may sustain themselves while taking care of our many needs, not to mention the needs of the organisms that live in them. Tinkering with the system without knowing the nuances of how it works can spell trouble for our oceans and our planet.

There is a lot we can learn about the ocean without having to get too wet. Today we're going to learn about two ocean habitats and their food webs, and what we can do to make sure these habitats stay healthy. We'll learn about how sailors have historically found their way around the oceans without a roadmap. We'll also learn how technology has changed how we collect and analyze data, and about the technology we use to sail the deep blue seas today. In six stations we'll use navigation skills to find out where we are when we make a plankton tow, investigate the ecology of a kelp forest and how sea otters and sea urchins keep their habitat in balance or how a coral reef provides habitat and protection to many species, take weather and water quality monitoring data, collect and analyze plankton samples, discuss watersheds and inputs into coastal systems, and we'll talk about how some of the tiniest ocean creatures feed the largest mammal on Earth.

We are fortunate to be living near a national treasure, one that has restrictions on it so it will never have oil platforms, and where fish and mammals can thrive. What is a sanctuary? A sanctuary can be a number of things; a place of refuge, shelter, a safe haven for all who visit.

The oceans bordering our nation are under the protection of the National Oceanic and Atmospheric Association (NOAA). NOAA's National Marine Sanctuary Program seeks to increase public awareness of America's marine resources through scientific research, monitoring, exploration, and education programs. The sanctuary system was started in 1972 and now includes 13 sanctuaries on the east and west coasts, Hawaii, and American Samoa. These sanctuaries protect habitats as diverse as coral reefs, kelp forests, and underwater shipwrecks. Today you'll be venturing into the largest marine sanctuary, the Monterey Bay National Marine Sanctuary—it's one of the largest protected marine areas in the world. It contains the coast and offshore area from San Francisco down to Cambria, near Hearst's Castle, and covers 5,300 square miles. From the moment you enter the water here, you are in the sanctuary—it is all around you, there is no door or gate, no admission fee. Take a good look around you—all you can see is a sanctuary for marine life, and for you!

A C T I V I T Y   O N E

1 Navigation Station:
On Board or Dockside

20 minutes

Overview

The navigation group begins in the cabin of the vessel (or wherever navigation equipment monitors are located) where they receive one compass per student. The instructor discusses how to read the navigation monitors and use the compass. Students move to the side of the ship where they observe local landmarks while gathering data to plot their location. They record compass bearings, wind speed and direction, depth, and temperature from monitors and record them on a data sheet along with other environmental observations.

DOCKSIDE MODIFICATION

Students take compass bearings, record hand-held GPS reading, and record environmental data from the dock. No radar or other navigational technology will be discussed.

Science Concepts

- Navigation is the art and science of conducting a vessel safely from one location to another
- Nautical charts are the road maps of the sea
- Tools used in navigation range from hand-held compasses to radar and global positioning systems
- Lines of latitude and longitude are used to chart position on the earth
- Triangulation is the geometric process of determining a geographical position using two or more compass bearings. Traditionally, sailors have used this method to determine where they are located on the nautical chart, but new technology, such as GPS, uses satellites to determine a ship's location.
- Compasses use Earth's magnetic force to determine direction.

Activity Background

Overview. The activity begins with a teacher-led discussion on electronic navigation equipment concepts and use. Students are then given a compass and instructed in its use. Students take compass bearings based on points of land and record them for later transfer onto navigational charts. Other environmental factors are observed and measured.

Objectives. Students are introduced to navigational tools, old and new, and understand how they are used by sailors to find their location at sea. Students will learn how to use a compass and how to take compass bearings.

Introduction. Begin with a teacher-led discussion on navigation concepts and how they are used in marine navigation. While on the dock, ask general questions (and wait for student answers) such as:

- **Have you ever navigated before? What did you do?**
- **How did you know where to go?**
- **How many of you could find your way from your bedroom to the kitchen to get a snack—in the dark?**
- **Sailors use many different tools to navigate. Can anyone tell me what types of tools sailors use to navigate?** Navigational tools include compasses, global positioning systems (GPS), radar, sextant, navigational charts, parallel rulers, depth gauge.

Move onto ship, or where navigation equipment is located.

- **When you go on a trip, or even across a big city, how do you find your way?** What streets do you take, and how do you know which direction to go on them? What tool do you use to find your way on land? Maps.
- Pass around the nautical chart display sheet. Discuss the difference between a map and a nautical chart. Maps have streets, cities, mountains, valleys, and buildings that can be used as landmarks. "Maps" of the ocean are called charts because when you are away from shore there are no "landmarks" on the ocean. A nautical chart also has information on landmarks as they would be seen from the water, for when you are near shore and can see them. When sailors are out at sea, they rely primarily on latitude, longitude, compass

Materials

Shipboard Station

- Global positioning system (GPS)
- Radar
- Single side band radio
- Depth gauge
- Speed indicator
- VHF radio
- Weather fax *(optional)*
- Hand-bearing compasses *(one per student)*
- Field data recording sheet, clip board
- Section of local nautical chart with detailed compass rose on it for display only *(laminated)*
- Map of the world with lines of longitude and latitude *(laminated)*

Note: images for photocopying are in Appendix H.

To take a bearing, the compass should be held an arm's distance from your eye. This may be challenging for younger students.

Introduction, cont.

angles, and depth soundings for navigation. A nautical chart is like a topographic map of the sea.

- **Does anyone know what latitude and longitude are?** Pass around the map of the world with lines of longitude and latitude. For purposes of navigation on the oceans where sailors can't see land to make bearings, Claudius Ptolemaeus (90 - 170 AD) invented the grid system of latitude and longitude. The sun and stars are used for bearings. Lines of longitude go from the North Pole to the South Pole. Lines of latitude circle the globe and go in an east/west direction. **Is the equator a line of latitude or a line of longitude?** The equator is a line of latitude.
- Point out a chart on the global positioning system screen. **Does anyone know what a GPS is and how it is used?** GPS stands for global positioning system. A GPS is a computer that contains nautical charts of every ocean in the world and can communicate with satellites to help you find where you are on land or sea. GPS uses lines of latitude and longitude to tell you where you are on a computerized nautical chart.
- **How does it work?** GPS uses satellites. A satellite is a celestial body orbiting another celestial body of a larger size, or a manufactured object intended to orbit the earth, moon, or another celestial body. The shipboard GPS computer receives a signal from satellites circling the earth. The computer calculates the boat's latitude and longitude and plots a cursor on the chart on the screen. That cursor will show exactly where the boat is at all times.

This photograph indicates the correct arm position for reading a hand-bearing compass.

Materials

Dockside Station Alternative

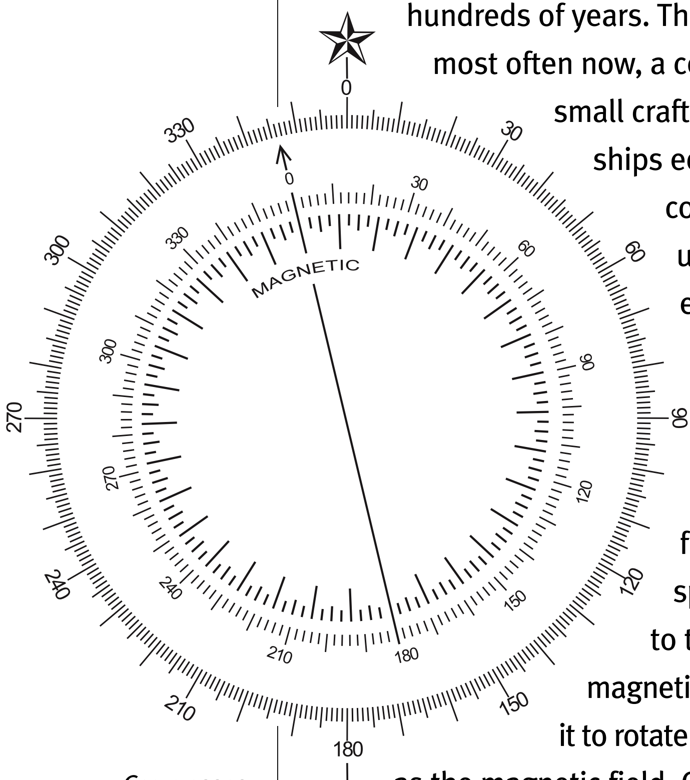
- Handheld global positioning system (GPS)
- Hand-bearing compasses *(one per student)*
- Field data recording sheet, clip board
- Section of local nautical chart with detailed compass rose on it for display only *(laminated)*
- Map of the world with lines of longitude and latitude *(laminated)*

Introduction, cont.

- Another navigational tool sailors use is radar. Radar stands for Radio Detecting and Ranging. Direct students' attention to the radar screen. Radar uses echoes. **What's an echo?** An echo is created when sound waves are sent out and bounce off an object, then return to the sender. Radar uses echolocation to "see" things on top of the water around the boat by sending out a high frequency radio signal. When the radio signal comes in contact with a solid object, it bounces, or echoes, back to the boat. Indicate a few points of interest the students might recognize on the radar screen. The boat is in the center of the screen, and the solid line indicates forward. What might be creating the electronic echo you see on the screen? Show students how you can adjust the range and scale of the radar. Students will probably see the shoreline on the radar. What might the other objects be that show up in the water? Other objects that may show up could be buoys, rocks protruding from the ocean, islands, or other boats. What else might be on the radar screen that bounces a signal back to us? On windy days when the sea is rough, the tops of waves bounce back a signal.
- **Is there any place in nature you can think of where echolocation is used?** Bats, porpoises, seals, and whales use reflected ultrasonic sounds to find objects or prey.
- **When would radar be a good navigational tool to use?** Any time you may be near the shore but can't see the shoreline with your eyes: at night, heavy fog, or rain.

Onboard Navigation Activity—
How to read a hand-bearing compass

Teacher Background. One of the most commonly used navigational tools is a compass. Magnetic compasses have been used for navigation for hundreds of years. Though electronic equipment such as GPS is used most often now, a compass is still a practical tool for navigation for small craft and for people on foot, and even airplanes and ships equipped with more sophisticated equipment carry compasses as backups. All the new technology relies upon electricity, and what would happen if they lost electrical power? Compasses don't need electricity to work. Most compasses operate on the same basic principle: a small, elongated, permanently magnetized needle placed on a pivot rotating freely in the horizontal plane. Earth's magnetic field results from electric currents in the earth's spinning molten iron core. This field is shaped similar to the field around a simple bar magnet. Earth's magnetic field exerts forces on the compass needle, causing it to rotate until it comes to rest in the same horizontal direction as the magnetic field. Over much of Earth, this direction is roughly true north, which accounts for the compass's importance for navigation. Once you know where north is, you can find all points on the compass rose.



Compasses designed for navigation, hand-bearing compasses, are read from the side, or outside edge. These instructions are for a hand-bearing compass.

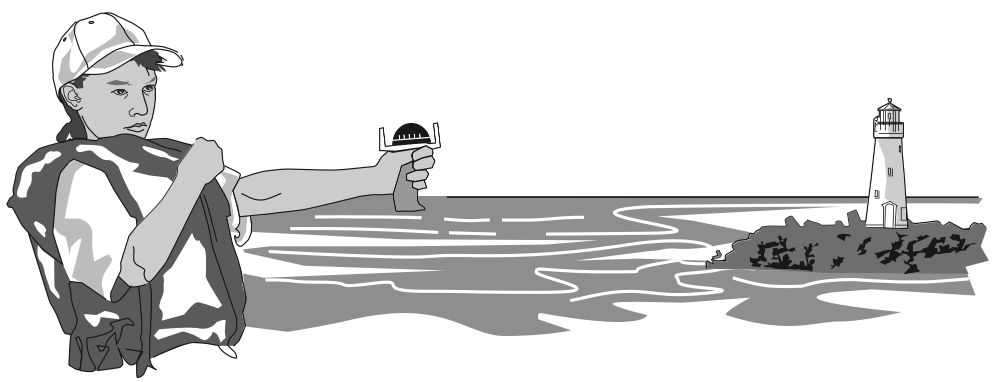
This hands on activity takes place on deck of vessel or dock with clear view of landmarks.

- Hand out one compass to each student and a compass and data sheet to one student volunteer. We'll use a compass and land marks to find out where the ship is right now. We'll take compass bearings and plot them on a nautical chart when we get back to land.
- Have students turn around in a circle, keeping their eyes open to look all around them. You just completed a circle. **How many degrees in a circle?** There are 360 degrees in a circle, so students just turned 360 degrees. As

Onboard Navigation Activity
continued

you stand in the center of an imaginary circle and look in a horizontal line out from the circle, every direction you look has a compass bearing, a number, measured by how many degrees the direction you are looking is away from north. North is 0 or 360 degrees. Have students look at their compasses and face east (90º), south (180º), and west (270º). Note some familiar landmarks at each of these directions. Remind students the sun rises in the east and sets in the west. Have students predict where the sun will rise and set if they were on the boat at sunrise and sunset.

- **How do you read a number line?** From small to big, left to right. A hand-bearing compass works like a number line, except it goes from right to left, from small on the right to big on the left. As you move to the left on the compass, the numbers go up, and as you move to the right, the numbers go down. Have students look at their compasses to see which way the numbers go.



Students hold the hand-bearing compass with a straight arm just below eye level, and point it directly at a landmark. They read the bearing from the side of the compass facing them.

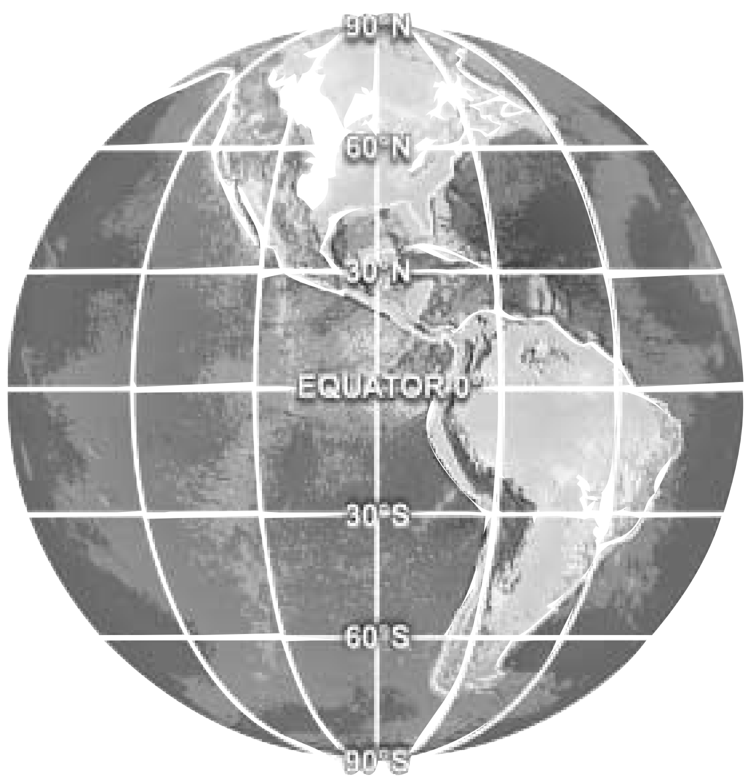
- On your compass, each line counts for a certain number of degrees. **Can you figure out how many degrees on the circle each line counts for?** On most hand held compasses, each line counts for five degrees. Look 6 lines to the left of North. **How many degrees is that?** If each line counts for 5 degrees, then six lines to the left of North (0 degrees) would be 30 degrees. **How about 6 lines to the right?** Six lines = 30 degrees therefore 360-30 = 330 degrees.
- The direction you look to see an object and find out its direction, in relation to

Onboard Navigation Activity
continued

you is called its azimuth or bearing; the process is called "taking a bearing." Now have a student call out an object and let the other students call out its azimuth. They should give the direction, in degrees, that they look to see it.

- Have students choose a site on land they can identify. This can be a lighthouse, mountaintop, or any large feature of land that will show up on the nautical chart. Hold your compass straight, and point it at the landmark. What is this object's bearing, or azimuth? Have students read their compasses and state their bearing one at a time. If it looks like all understand how to read their compasses, then proceed to choose three landmarks from which they can take bearings. Have the student recorder record their bearings and the time on the data sheet.
- Move the group to a location where they can see the depth gauge. Have the students read the depth gauge to record the depth of the ocean at the same location of their compass bearings. They will round the depth reading to the nearest foot. Collect other environmental data on record sheet (wind speed and direction, weather observations, etc.).

For purposes of navigation on the ocean where there are no landmarks to make bearings, sailors use lines of longitude and latitude. Lines of longitude go from the North Pole to the South Pole. Lines of latitude circle the globe in an east/west direction. The equator is a line of latitude.



Wrap Up

Anyone who is out on open water needs to know where they are in relation to land. Many migrating marine mammals also use landmarks along the coast to get their "bearings." Gray whales spy-hop, and toothed whales echolocate on subsurface features, navigating the same seas year after year. Whenever scientists go out in the field, they make observations and collect data. Where the samples or observations were made—their location—is one of the most important pieces of information scientists need. Every bit of environmental information about the scientific cruise is written down on a data sheet. On this cruise we are taking a plankton sample back to the classroom to look at under a microscope. We will need to collect data such as date, time of day, location, weather conditions, temperature, wind speed and direction, water depth, and any unusual things we saw such as a dolphin, whale, or sunfish. Why do we collect this data? Scientists make observations and collect data to understand how things work. Then they make hypotheses based on their observations.

Explain to students that back in the classroom we will plot these bearings on a nautical chart to determine where the ship was when we took the plankton tow.

School/Organization__________________ Date_______________ Group ________ Time _________

O'Neill Sea Odyssey Navigation Data Sheet

BEARING #1 ________ LOCATION __________________ BEARING #2 ________ LOCATION __________________

BEARING #3 ________ LOCATION __________________

GPS FIX: LATITUDE ______ degrees _______ minutes _______ seconds

LONGITITUDE ______ degrees _______ minutes _______ seconds

WIND SPEED ______________knots DEPTH__________________feet

WEATHER OBSERVATIONS: sunny — light fog — heavy fog — partly cloudy — overcast — light rain — heavy rain

A C T I V I T Y T W O

2 Marine Biology Station:

On Board or Dockside

20 minutes

Overview

The marine biology group takes part in deploying a plankton net and conducts a plankton tow off the stern of the boat. They transfer the sample into a collecting jar for later analysis. Students observe the ocean, birds, and mammals while learning about interactions of oceanic food webs and food chains. The group records environmental observations on a data sheet.

DOCKSIDE MODIFICATION

Students take the plankton tow off the dock by taking turns walking up and down the length of the dock, towing the net behind them for 10 minutes. They take the secchi disk reading from the deepest end of the dock, and record all environmental variables and observations on the data sheet.

Science Concepts

- The ocean is the major component of Earth's biosphere
- Seawater has specific environmental factors that make life in the sea possible, including pH, temperature, water clarity, and nutrients.
- Plants and animals in the ocean require seawater for survival, to collect food, reproduce, and disperse eggs, larvae, and spores.
- Food webs in the ocean depend upon phytoplankton for survival.
- A typical Pacific Ocean food web includes phytoplankton, zooplankton, invertebrates, fish, birds, marine mammals, and humans.
- Coral reef food webs are based on coral and the symbiotic algae growing in coral tissues.
- Coastal upwelling centers contain the world's most productive fisheries and

Activity Background

Overview. Students conduct a plankton tow, read a secchi disk, take a pH sample, listen to a discussion of oceanic food webs, and record natural history observations and environmental data on a data sheet.

Objectives. Students participate in a hands-on biological sampling procedure. They will know the marine food web is based on plankton, and make the connection between ocean water quality and the importance of sustaining intricate food webs. Students will observe the abundance and diversity of marine life in the sanctuary.

Introduction. Teacher-led discussion on marine biology concepts and oceanic food webs and chains. Ask general questions (do not correct misinformation at this time) to assess student understanding of the marine sanctuary,* plankton, primary producers, consumers, and food chains and webs. If students have broad science content knowledge and can answer these questions easily (and correctly), move on to the activity.

- **Why do so many birds, fish, mammals, and invertebrates live here in the sanctuary?** Unique features of California's central coast contribute to spring upwelling. Nutrient rich water that supports many different marine organisms.
- **What does the word "biology" mean?** The study of all living things. "Marine"? Anything having to do with the sea. Marine biology is the study of life in the sea, covering all living marine plants, animals, protozoa, and bacteria, from microscopic bugs to the largest mammals on Earth, blue whales. Marine biologists look at questions such as how marine mammals stay warm in frigid waters, what types and how many fish are there in the sea, how sea stars reproduce, and how fast kelp grows.
- **What is the biggest environment on Earth?** The open ocean. It covers more than 70 percent of Earth's surface, almost three-fourths of the planet, and contains 95% of Earth's living space and provides 50% of Earth's oxygen.
- You are visiting the biggest environment on Earth, but can't really see most of it. Why not? It's underwater, and very deep. What we see on the surface is a

** Activity 2 is fully applicable to all temperate, cold water coastal locations on the West Coast and to the Gulf Coast states. Plankton tows can be done from a boat, along side a dock or with hand nets (warm water). National Marine Sanctuaries in these areas are: Olympic Coast NMS, Port Angeles, WA; Gulf of the Farallones NMS, San Francisco, CA; Cordell Bank NMS, Pt. Reyes, CA; Monterey Bay NMS, Monterey, CA; Channel Islands NMS, Santa Barbara, CA; Flower Garden Banks NMS, Bryan, TX.*

Science Concepts
continued

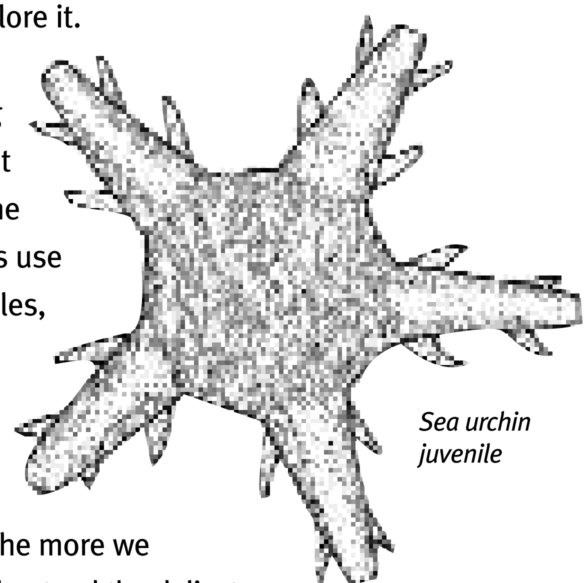
marine mammal foraging areas. These centers are responsible for approximately 95% of the annual global marine productivity.

- Due to wind-driven seasonal upwelling, Monterey Bay is one of the richest marine environments on Earth.
- During the spring in normal years, Monterey Bay's northwest winds blow along the coast between Año Nuevo and Davenport. These winds bring cold, nutrient-rich water to the surface in a process called upwelling. The rich water feeds an explosive growth of phytoplankton and provides the base of a food chain ultimately leading to high concentrations of feeding blue and humpback whales in the summer. This increased production fuels the entire food web consisting of

Introduction, cont.

tiny fraction of the activity beneath. The ocean is deep and wide, holding many secrets scientists work to uncover. It is a challenging place to work and special equipment is needed to explore it.

- **How do people study it?** Like those who study space, scientists studying the ocean require special equipment to explore, observe and study marine life and processes. Marine scientists use technology to develop remote vehicles, underwater sampling devices, and tethered monitoring stations to explore the inner space of the oceans. Technology is key to exploring areas difficult to access. The more we learn about oceans, the more we understand the delicate balances in ocean ecosystems, and how much we rely on the oceans to support life on Earth.



Sea urchin juvenile

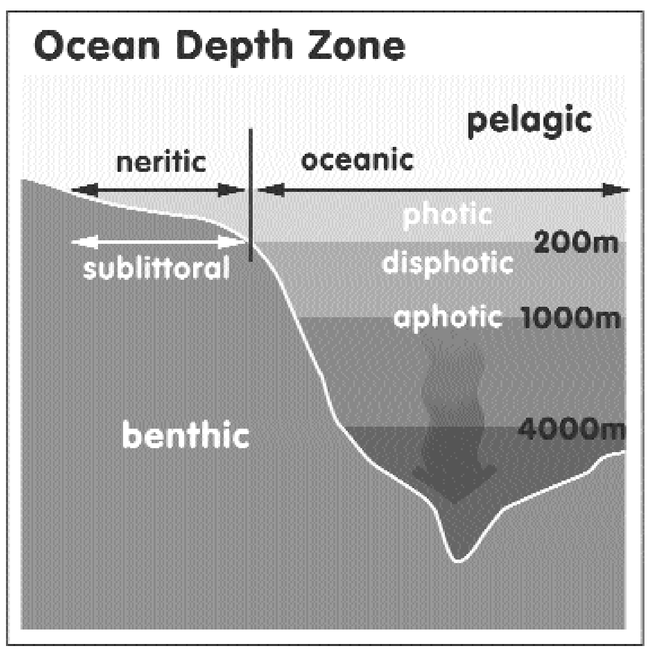
- **Where does most of the life in the sea live?** Although the sunlight zone (photic) of the ocean is only the top layer and makes up a small part of the entire ocean, more than 90 percent of all marine life lives there (see illustration). The shallower areas near the continents, where nutrients from land wash down through rivers and streams, are the most productive and species rich areas in the ocean.
- Because the ocean covers so much of the Earth, a lot of sunlight lands on it. **What happens to this sunlight?** On land, light energy is transferred into plant energy by trees, grasses, and land plants. In the ocean, everything is seawater-based, and light energy is collected by attached algae and many tiny floating plants (phytoplankton). The ocean acts like a huge solar collector transferring light into food energy. The photic, or light zone, goes to an average depth of 300 feet—the length of a football field. The deeper you go, the darker it gets, until you reach depths of 600 feet where it is pitch black. Organisms living below 600 feet may glow in the dark and have strange adaptations to living in frigid darkness.

Science Concepts
continued

resident and migratory fish, mammals, and sea birds.
- Scientists use tools to gather scientific data about plankton. Some of these tools include a plankton net, Secchi disc, depth finder, thermometer, and depth gauge
- Activities we conduct on land influence oceanic water quality. Water quality determines abundance and distribution of plankton and the species depending upon them, from krill to whales.

Introduction, cont.

- **How do plants turn light energy into food?** Photosynthesis is a chemical process where plants turn light energy into chemical energy. The plants grow bigger and multiply faster, making them nutritious food for other animals in the ocean.
- **What are primary producers?** Plants are primary producers, because they are the first to produce energy for others to eat. Plants on land and in the ocean collect light and use photosynthesis to grow and multiply. Phytoplankton are the grasses of the ocean, and the most important part of the ocean's food web; they need sunlight, nutrients, the right temperature, and seawater free of harmful bacteria or chemicals to survive. Today we'll collect and look at plankton, the most important link in oceanic food chains.
- **What do you know about plankton?** How do plankton move? Are fish considered plankton? Are plankton big or small, plants or animals? Are bacteria plankton? Adapt the following material to address the group's level of understanding.
- **What is plankton?** The word plankton comes from the Greek word meaning wanderer. Plankton are plants and animals in marine and fresh water environments that drift with currents, tides, and wind, and have little or no ability to move on their own.
- **How big is it?** Most, but not all, plankton is microscopic, but many, like jellies, are large enough to see easily.
- **Is plankton plant or animal?** Both. Plankton can be plants or animals; phytoplankton are plant plankton, and the slightly larger animal plankton are zooplankton.
- All plankton is either holoplankton or meroplankton. Holoplankton are small complete organisms that spend their entire life as plankton, such as tiny crustaceans like the krill eaten as food by many fish



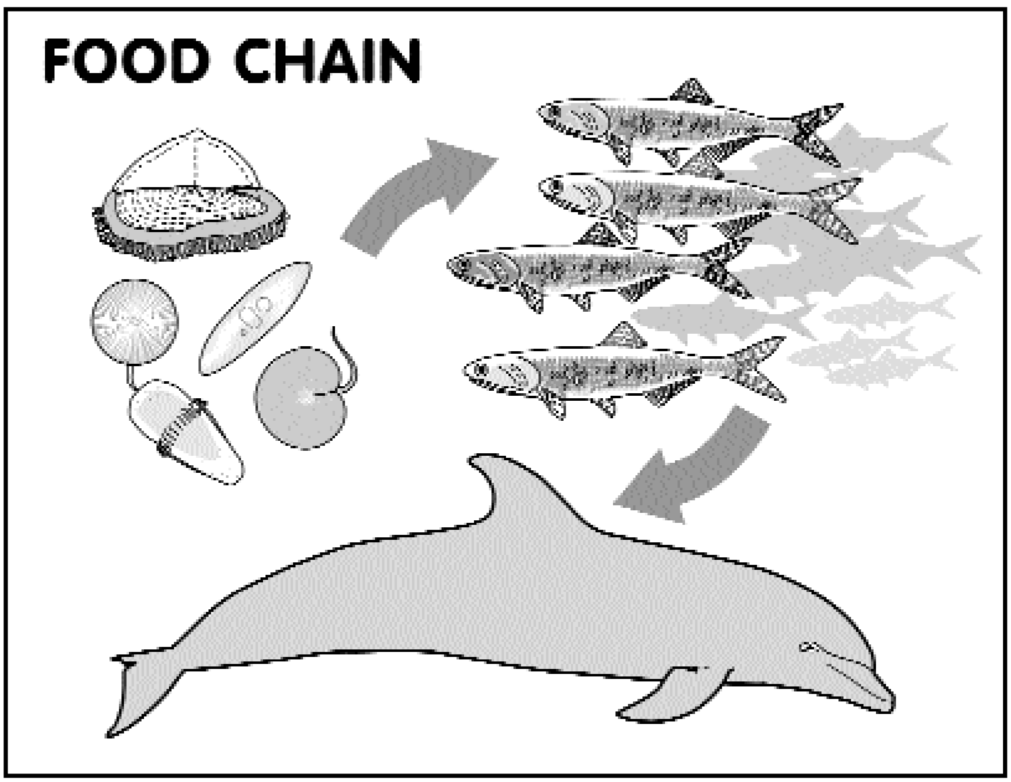
Expected Outcomes

- Recognize because life in the sea happens below the surface, it is difficult to observe firsthand the seasons of the sea; indirect observations and measurements must be used, such as salinity, water temperature, and types of species present
- Plankton are specially adapted to life in the sea and are the primary producers on which oceanic food webs are dependent
- Understand the structure and purpose of a plankton net. Have hands-on experience with deploying a plankton net and collecting the sample
- Use teamwork to collect plankton samples and record data on water temperature, depth, windspeed, and water visibility
- Students will understand that life in the sea has seasons based on day length, water temperature, and atmospheric conditions.

Introduction, cont.

and whales. Meroplankton are organisms that are planktonic for only a stage of their life cycle, usually the larval, egg, or spore stage. Many invertebrate larvae are meroplankton before they settle and attach to rocks.

- **If they are so small, why are plankton so important?** Either indirectly or directly, all life in the sea depends upon phytoplankton for food.
- Plankton are the most important link in ocean food chains and webs. **Who knows what a food chain is?** A food chain diagrams energy flow in an ecosystem. Energy from food passes from one organism to another in a sequence, similar to the links of a chain. One example: phytoplankton is eaten by zooplankton; zooplankton is eaten by small fish like anchovies, and anchovies are eaten by brown pelicans. When pelicans die, they decompose by marine bacteria. A food chain includes a producer (phytoplankton), a consumer (organisms that eat producers), and a decomposer (mainly bacteria).

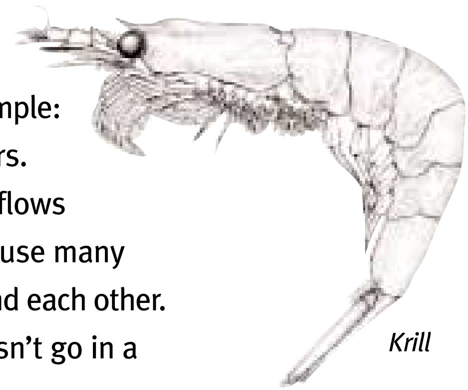


- **How is a food web different from a food chain?**
Food webs are built of food chains—the chains are like the connecting strands of the web. A food web distributes energy from the sun to plants, then to larger animals unable to use the sun's energy directly—these animals are

Expected Outcomes
continued

- Understand collecting data at different times of the year and at different locations is important to better understand patterns in species diversity of plankton, their consumers, and connections to the oceanic food web dynamics.

Introduction, cont.



Krill

called consumers, because they can't make their own food they must consume it. For example: fish, whales, seals, and sharks are consumers. A food web is a better model of how energy flows through ecosystems than a food chain, because many animals eat a lot of the same kinds of food, and each other. In nature, the transfer of energy usually doesn't go in a straight line.

- One of the most important zooplankton in the world is krill. **What are krill, and how do they fit in the oceanic food web?** Krill are small, floating crustaceans that look like a little like pink shrimp, and average an inch long (show sample). Krill cluster in huge masses (swarms) containing billions of individuals. Krill eat phytoplankton, mainly diatoms. Most predators in the sanctuary (including humans) are only one or two links in the food chain away from krill, and krill is the primary prey of seven of the ten most important commercial fishes on the central California coast. Over 95 percent of the diet of endangered blue and fin whales consists of krill.
- Take a few minutes for students to observe birds, mammals, and other sea life visible from the boat. When possible, identify sea life for students along with interesting natural history notes. Ask students what they think the connection is between phytoplankton and the species they see. Mention all the species they see today depend in some way on the plankton that they are sampling.

Materials

- Two plankton nets, one for use and one to pass around the group
- Clipboard, pencils, and data sheets
- Specimen tubes and portable cooler
- Thermometer and fathometer displays
- Bucket to collect water sample for pH sample
- 500 ml nalgene bottle
- Secchi disk
- pH meter
- Laminated illustration of a food chain
- Preserved krill in a jar.

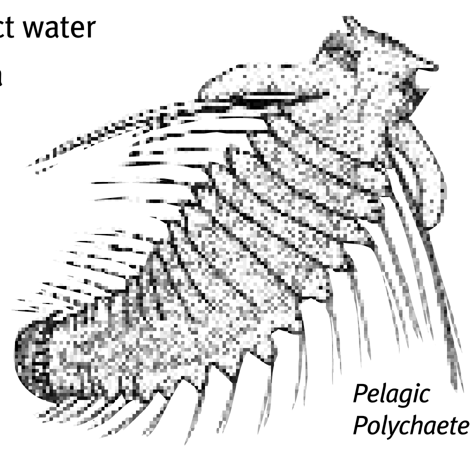
Note: images for photocopying are in Appendix H.

Onboard Marine Biology Activity—

Students collect plankton & environmental data.

This is a teacher led discussion with plankton net deployment.

- As you get out plankton nets, lead a discussion on the types of plankton you might collect, and why. Plankton have limited swimming ability, and are at the mercy of currents, tides, wind—and plankton nets. They can only move as fast or slow as these forces. Discuss the influences of diurnal and seasonal patterns on plankton abundance (daylight phytoplankton at surface, zooplankton below; nighttime zooplankton surface and phytoplankton below), and how the time of day and time of year can influence what species you get in your plankton net (upwelling events, El Niño). In Monterey Bay, spring winds trigger summer upwelling; phytoplankton grow rapidly creating dense blooms sometimes coloring the water a deep red (a red tide).
- Hold up plankton net for students to see. Hand around sample plankton net for students to pass around, assemble, disassemble. Demonstrate parts of the net and how it works. The nylon fabric mesh is so small you can barely breathe through it, but water can get through the pores in the fabric. A plankton net works like a filter. **Have you ever used a filter or a sieve? Have you ever strained noodles in a colander?** Filters let small particles get through but keep large particles back. Many ocean animals feed by filtering their food from seawater. Can you think of any? Here in Monterey Bay Marine Sanctuary, blue and humpback whales, anchovies, mussels, clams, barnacles, sea squirts, and oysters are all filter feeders. Plankton nets work in a similar fashion to filter feeding organisms; they both collect water containing plankton, then force it through a sieve with pores large enough for the water to get through but too small for the critters left behind. Describe the different types of filter feeding as employed by baleen whales, basking sharks, fish, and many benthic invertebrates. These animals spend

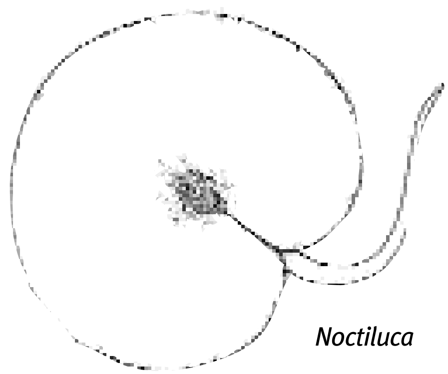


Pelagic Polychaete

Illustrations from A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae, Second Edition, *by DeBoyd L. Smith and Kevin B. Johnson. ©1996 by DeBoyd L. Smith and Kevin B. Johnson. Reprinted by permission of Kendall/Hunt Publishing Co.*

Onboard Marine Biology Activity
continued

most of their time filtering seawater for food. Sometimes whales feast on "bait balls" of krill, concentrations that form due to underwater features such as submarine canyon walls, water currents, and upwelling of cold nutrient rich water.

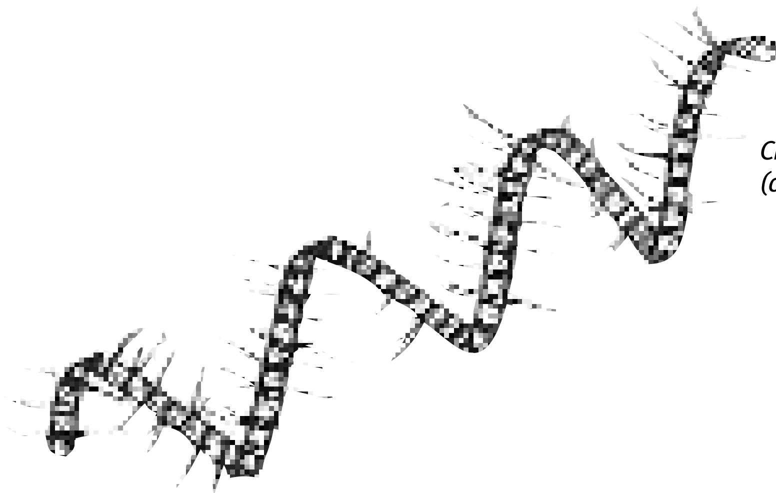


Noctiluca

- Have 3-4 students deploy the plankton net. As a group record time, water temperature, water depth, and other environmental variables on data sheet (swarms of fish or flocks of birds nearby). Keep plankton net in water for five to seven minutes. Discuss with students how the ocean is not uniform, and the species they collect from this surface plankton tow during the day are very different from those collected at a depth of 100 feet, or at night, or in a different part of the bay. Back in the shoreside lab, we will use a microscope to see what we've collected. We'll see if there are differences in the plankton samples collected at the three sites today and at these same sites by classes on other days.
- Have 3-4 students cooperatively bring the plankton net back to the boat, and have one student pour the sample into a collecting bottle held by another student. Have students pass the bottle around and describe what they see. Explain plankton can be all sizes, from microscopic, to the size of sand specs, to large jellies (not caught in our net as the bottle is too small—you need special nets to catch jellies).
- If it is a relatively calm and windless day, deploy the secchi disk. Have students work in cooperative groups, one holding the disk, one reading, and one recording. Assist them as needed. Discuss how water clarity may affect plankton abundance. Have students note the color of the water and note on data sheet—blue, green, red? Each tab on the line measures number of feet. Have students slowly lower and watch the disk until they can't see it any more. Right when they lose visibility, have them lift it back up so they can see it and record that as the depth of visibility.
- Place a bucket on a rope over the edge of the boat. Collect a surface water sample in the bucket, and pour enough of the seawater to a fill a 500 ml collecting jar.

Onboard Marine Biology Activity continued

- There are so many subtle ways we affect life in the sea, we discover more every day. We must be cautious how we use our oceans because we still don't have all the answers.



Chaetoceros (chain)

Illustrations from A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae, Second Edition, *by DeBoyd L. Smith and Kevin B. Johnson. ©1996 by DeBoyd L. Smith and Kevin B. Johnson. Reprinted by permission of Kendall/Hunt Publishing Co.*

If you have time in the session, bring up a local issue students may be familiar with and show how plankton are related to it. Here is a sample from the Monterey Bay sanctuary.

Are all plankton "good" plankton?
Depends on how you define "good!" What is good for some organisms can be toxic to others. Take the case of harmful algal blooms (HABs). When nutrient and water temperature conditions are right, phytoplankton can divide rapidly and create a "bloom" just like a spring bloom of wildflowers. This is good for the zooplankton feeding on the phytoplankton. But there are some species of phytoplankton that create toxic blooms responsible for poisoning seabirds and marine mammals, and can interfere with fisheries. Harmful algal blooms caused by certain species of diatoms (single-celled algae with glass shells) in the genus *Pseudo-nitzschia* blooms in Monterey Bay from late spring to early fall. The algae produce domoic acid, a potent neurotoxin that can cause nervous twitching, disorientation, short-term memory loss and even seizures and brain damage. Domoic acid is passed up the food chain from diatoms to small fish and copepods to larger fish, seabirds, sea mammals, and even humans. It becomes more concentrated the further up the food chain you get; a seabird will feed on many fish that have fed on many zooplankton that fed on many toxic algae. Sometimes in the spring you may see a sea lion or a marine bird on the beach, walking in a drunken gait—he might be under the influence of domoic acid! Alfred Hitchcock's movie "The Birds" was based on a real life incident that happened right here in Monterey Bay. Capitola, a sleepy beach town, was terrorized for a few days as crazed sea birds ran into windshields, through windows, and down chimneys in the 1940s. Scientists now think these birds were feeding on fish that contained domoic acid—a naturally occurring poison! Other toxic algae create paralytic shellfish poisoning, and some months of the year it is not safe to eat local shellfish such as clams or oysters. They won't be served restaurants when they are poisonous, but if you collect them on your own, be sure to check with a local bait shop to see if they are safe to eat.

Wrap Up

Life in the sea depends upon its smallest organisms. The Monterey Bay National Marine Sanctuary is one of the richest, most diverse marine environments in the world, largely because of unique underwater features and wind conditions that produce upwelled nutrient rich water. In surface waters, plankton use these nutrients to increase in numbers, and form the base of the food web supporting thousands of species in the sanctuary from krill to whales.

School/Organization__________________ Date_______________ Group ________ Time _________

O'Neill Sea Odyssey Marine Biology Data Sheet

TEMPERATURE ________________F VISIBILITY ________________ft

DEPTH ________________ft SALINITY ________________ppt pH ________________

WATER COLOR: brown blue red green yellow-green blue-green

PLANKTON SAMPLE NUMBER ________________

PLANKTON OBSERVATIONS: mostly zooplankton mostly phytoplankton about half and half

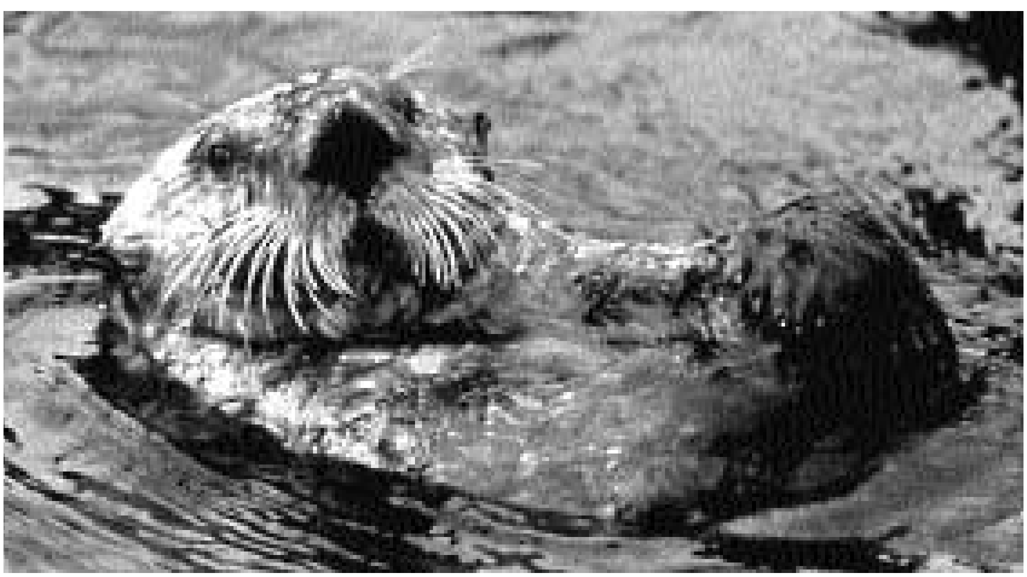
OTHER SEA LIFE OBSERVATIONS: ____

3 Marine Ecology Station: Kelp Forest (On Board or Dockside)

20 minutes

Overview

Students first observe the surrounding environment, looking for signs of marine life evident above the surface. They then mentally submerge themselves in a kelp forest* to explore the food webs, unique residents, incredible diversity, human uses, and high productivity of kelp beds. Hands on visuals include a sea otter pelt, live kelp, a fishing net, and a display on marine debris and decomposition of plastics. Students brainstorm ways that humans impact kelp forests and problem solve how to reduce negative impacts.



DOCKSIDE MODIFICATION

This activity may be conducted on a dock with no modifications necessary.

** Marine habitats vary widely from coast to coast—kelp forests and coral reefs are highlighted here, but seagrass beds and other local coastal habitats are applicable using these same concepts.*

Science Concepts

- Marine ecology is the study of ocean habitats, including the environmental factors and resident and migrating species adapted to these habitats.
- The sanctuary protects many different habitats, including sandy beaches, rocky intertidal, soft bottom, kelp forests, and open ocean. Each habitat has food webs containing organisms adapted to their environment.
- Kelp forests are similar to terrestrial forests; they are based upon plants, they have characteristic canopy and understory plants and animals, and provide sustenance and protection for many other organisms including fish, invertebrates, mammals, and birds. Kelp forests are nurseries for some juvenile fish. Without kelp forest habitats, many of these organisms would not be able to survive.
- The California sea otter, an endangered

Activity Background

Overview. The instructor describes Monterey Bay sanctuary habitats while students observe the wildlife that surrounds them, viewing what they can from the surface. Using fresh kelp, food web diagrams, photos, and a sea otter pelt, the instructor and students explore the elements of the kelp forest and identify residents in the ecosystem. Students understand a kelp forest is an example of a marine ecosystem supporting an endangered species (keystone species: sea otter). Students handle kelp, sea otter pelts, and a ghost fishing net, view photos of how debris harms sea life, and view a waste decomposition display. Students make the connection between our actions on land and how they impact kelp forest residents. Students examine the sources of marine pollution and brainstorm what they can do to reduce marine debris and non-point source pollution. Dockside option (requires student movement not appropriate on a boat): students also play a game where they are predators or prey and create a kelp forest food web.

Objectives. Students define an ecosystem and what is different between marine and terrestrial ecosystems (i.e., the different environmental variables and special adaptations of organisms to the environment). Students identify and know special adaptations of four kelp forest organisms, and are able to describe a kelp forest food chain and web. Students identify four threats to marine wildlife and habitats in the Monterey Bay Sanctuary and evaluate human influences on sanctuary ecosystems. Students know the difference between point and non-point source pollution and different threats to marine ecosystems from both sources.

Introduction. Assess student general knowledge of marine ecology, ecosystems, food webs, kelp forests, and marine pollution. If students are not familiar with these topics (this will be partially dependent on amount of classroom preparation before the cruise, and the order in which the stations are presented today) take a quick moment to review the terms (see marine biology section on food webs; students get a complete description in the marine biology activity). Ask questions and wait for an answer before proceeding.

Science Concepts
continued

species, is a keystone species of the kelp forest. Keystone species affect the ecosystems in which they live. Sea otters eat sea urchins and other animals that graze on kelp. Human activities affect sea otters' ability to sustain a viable population.

- Kelp forests are useful to humans, too. In addition to recreational diving opportunities, humans harvest kelp to obtain algin and carrageenan, extracts having properties useful in foods and other commercial products.
- Human actions impact marine habitats and affect their ability to sustain life.

Introduction, cont.

- Today we'll talk about some of the habitats in the Monterey Bay National Marine Sanctuary, how they were formed, some of the critters living there, and what we can do to keep these habitats safe.
- **Do any of you like to fish? Do you like to eat fish, or shellfish like clams or oysters? Do any of your parents, or grandparents collect their food from the sea?** People have been taking food from the sea for thousands of years. Entire cultures have developed based on food from the sea. Many families still keep their connection to fishing because of fond memories of fishing with their parents or grandparents. Fishing is why many people immigrated to California in the 1800s—Monterey Bay has a long and proud history of immigrants from Spain, Italy, China, Portugal, and other countries where fishing is a way of life. These people came because they could make a good living fishing. Monterey Bay is known to have an assortment of plants, fish, shellfish, and mammals. Many descendents of these people still live in the Monterey Bay area, and are interested in maintaining family traditions. Is it the same bay today as it was 150 years ago? Many more people live around the bay now, and pressures on the bay's once plentiful resources are building. Today we'll learn about how these pressures are affecting marine life in the sanctuary.
- From the sandy beaches to the Monterey Submarine Canyon, the Monterey Bay National Marine Sanctuary contains many habitats. In the oceans, habitats

Expected Outcomes

Students will be able to:

- Define the term marine ecology
- Understand what a National Marine Sanctuary is and some of the reasons an area would be designated a marine sanctuary
- Identify some activities that are acceptable in marine sanctuaries, and some that are not
- Identify at least three of the living resources of the sanctuary
- Identify adaptations of organisms to the marine environment
- Use a specific example of a plant and animal relation-ship in the sanctuary to describe how the marine environment supports itself and remains in balance (i.e., urchins, southern sea otter and kelp)
- Recognize the many impacts humans have on the marine environment
- Describe how land based trash and toxins affect

Giant kelp (Macrocystis pyrifera) *is the fastest growing plant on Earth. Giant kelp forests provide habitat for thousands of different plants and animals, from sea urchins to leopard sharks.*

are specific to depth and substrate, or bottom-type. Herethere are rocky and sandy shores, rocky intertidal, rocky subtidal, a submarine canyon, rocky reefs, kelp forests, and open ocean habitats. Where ocean meets land, there can be salt water marshes and wetlands (show illustration of bay habitats).

- **Have any of you ever visited a forest?** What was it like? (Have students list the characteristics of a forest; canopy, trees, understory plants, animals dependent on the plants, etc.) The ocean has forests, too, underwater forests having canopies just like a redwood forest. Fish and birds feed in the canopies, crabs climb over the rocky bottom and up the kelp plant and smaller fish feed on the tiny invertebrates living in and on the plants. Kelp forests even have mammals; sea otters, harbor seals and sea lions. Whales usually steer clear of kelp forests—they are too near shore, and are hard to navigate through—like a blimp in a redwood forest, the trees get in the way.
- **Are plants that live in the ocean like plants on land?** Plants living in water are specially adapted to use water instead of soil to grow. Most plants living in water are algae—marine algae or seaweed is like what you see washed up on the beach, the tide pools, or in kelp forests. Algae are primary producers getting all their nutrients from the water and energy from the sun. They are very flexible—the water supports them, and in fact, if they were hard and woody like land plants, waves would break them to pieces. Being flexible keeps them alive. Instead of roots, algae have holdfasts strongly attached to the surface of rocks. Because algae are plants needing sunlight, they only grow as deep as light can penetrate—about 100 feet deep. Most of them live in the upper 30 feet of the ocean.

Expected Outcomes
continued

marine ecosystems, and what consumers can do to reduce marine debris
- Identify three environmental issues in the marine environment
- Recognize the importance of watersheds and their impact on the marine region
- Identify land based sources of marine pollution

Materials

- Diagram of a kelp forest *(laminated)*
- Kelp forest food web diagram *(laminated)*
- Photo of kelp bed underwater *(laminated)*
- Sea otter pelt
- Kelp samples
- Examples of products containing kelp extract (algin and carrageenan)
- Portion of ghost net
- Waste decomposition chart

Note: images for photocopying are in Appendix H.

Onboard Marine Ecology Activity—
Making the land/sea connection

This is a teacher led discussion with hands on display items.

- A kelp forest is an incredibly rich habitat that serves as nursery, kitchen, and hunting grounds for thousands of different marine organisms, from sea otters to fish. Today we'll learn about what makes kelp forests such special places for us, and those who live in them.
- **Has anyone ever seen kelp? In the water or on the beach? What is kelp?** Kelp is a general name for a group of brown algae. (If you are near a kelp forest, have students note how the water is more still in the kelp forest, and any other differences they see.) The largest kelps form California's kelp forests. Other types of kelp forests are found in cold water off the coasts of Japan, South America, Great Britain, and New Zealand.
- **When you see smelly, rotting kelp on the beaches, do you wonder why there is so much here (and wish that it wasn't)?** In the sanctuary, upwelled water rich in nutrients helps kelp grow big and fast. The kelps that make up the forests in the sanctuary are the giant kelp *Macrocystis* and the bull kelp *Nereocystis*. *Macrocystis* has many long stems or *stipes* and small floats or *pneumatocysts*, and can grow over 100 feet long very quickly—14 inches on a sunny day in spring. It's one of the most productive plants on Earth! It has floats all along the stipe to buoy it close to the surface—and sunlight—as possible. (Pass around *Macrocystis* sample, encouraging students to pop some of the floats to see what is inside, and to bend it to see how supple it is, smell the kelp, and look at the surface of the blades.) The other large kelp, *Nereocystis*, has a single stem and one huge float on the top with a crown of long blades. These kelps can grow in water 60-100 feet deep and are the basis for a teeming city of fish, invertebrates, and some mammals. Instead of roots, algae gather nutrients from the water surrounding them—the whole body of kelp can make energy from sunlight, not just the blades. The blades are designed to maximize surface area and increase the area available to take up nutrients from the water. Kelp have large holdfasts, a structure designed to hold tightly to rocks, and the long, narrow plants are extremely flexible. The secure holdfast is another microhabitat where many other animals live, safe from predators.

Onboard Marine Ecology Activity
continued

The kelp forest marine ecology station uses hands on visuals to teach students about food webs, biodiversity, human impacts, and the high productivity of kelp beds.

- **It looks like a bunch of plants lying on the surface of the water. Why is it called a kelp forest?** Underwater, it's a very different story. (Use laminated underwater kelp forest photograph). If you had scuba gear, you could dive down and see the understory algae, just like understory plants in forests, thriving in this protected environment. You'd see many kelpfish swim by, nibbling on invertebrates living in the fronds, a sea lion chasing a fish through the forest, and an incredible assortment of sea urchins, sea stars, kelp crabs,

and anemones living on kelp and the rocky sea floor. Sea gulls float on the surface of kelp beds, picking off tiny invertebrates from the fronds. Diving birds such as cormorants swim through the forest as they chase down a fish, their wings pumping like powerful fins. (Look for birds exhibiting these behaviors).
- (Show kelp forest food web diagram.) Kelp forests are nurseries for larval and juvenile fish and invertebrates brought in with the currents. Some settle on plants and rocks and grow to adults, and some become food for others. Kelp forests have herbivores (sea urchins, abalone, and snails) which eat the kelp, and carnivores (otters, fish, sharks, and sea lions) which eat the fish and invertebrates in the kelp forest. Fish and invertebrates eat aquatic insects and plankton. Food webs in the ocean are structured in similar ways to food webs on land.

Onboard Marine Ecology Activity
continued

- **Fish, birds, and mammals use the kelp forests—how do humans use them?** Kelp forests support the richest group of sea life in any of the sanctuary's communities. One adult *Macrocystis* can harbor more than 500,000 sea creatures—many microscopic. Kelp forests slow down swells, making a protective slow-water environment for larval fish and invertebrates, and a safe place for adult fish and invertebrates to hide from predators and find food. Kelp forests benefit food chains outside the forest by exporting kelp fronds feeding creatures in rocky crevices. Kelp rafts, floating islands of detached kelp, create temporary habitat for some fish and invertebrates.

Students touch and smell the kelp, and sometimes taste it.

People have used kelp for years, first as fertilizer and potash, potassium carbonate, a chemical extracted from kelp used to make gunpowder. Extracts from kelp are used in food, drinks, and many other products. Algin, from brown algae, and carrageenan, from red algae, are useful as flavorless thickeners and emulsifiers adding body to ice cream, bread, beer, chocolate milk, cake mix, and shampoo.
- **Why do we have such thick kelp forests in the Monterey sanctuary?** The primary reason is the spring upwelling of nutrient rich water which promotes fast summer kelp growth. In addition, there is just the right combination of water temperature, and bottom type at the right depth. Kelp forests are thickest in late summer, with canopies stretching for miles along the coast. In winter, storms bring swells with up to 40 times the force of a hurricane ripping apart kelp forests. Winter storms thin out kelp forests, but when the days lengthen in spring and upwelling begins, the cycle begins anew.
- **Does harvesting kelp kill it?** Not if it's harvested properly. Kelp is harvested by hand or using special boats with lawn mower-like attachments snipping

Onboard Marine Ecology Activity
continued

off only the top 3 to 6 feet leaving the holdfast intact. Fronds grow back quickly. Kelp harvesting occurs in the sanctuary—more is harvested south of Monterey Bay, within sanctuary boundaries. In the sanctuary, abalone aquaculturists often harvest kelp by hand to feed their abalone.

- All members of the kelp forest community are adapted to living here—the water temperature, light requirements, nutrient levels, and bottom type define whether a species can survive or not in a habitat. If time, discuss one of these environmental parameters and what the effect of changing it would have (a change induced by something such as global climate change or decreased visibility due to runoff). For example: **Does temperature affect your life? How might the temperature of the water affect marine life?** We, who live on land are adapted to the air temperature of our surroundings —those who live in the oceans have special adaptations to water temperature, either cold or warm. For example, California sea lions have a thick layer of blubber to protect them from the cold water off the coast of California but this same layer would prove fatal in warmer water—they would overheat and die. The giant kelp is specially adapted to live in cold water and its strong, supple stipes are able to weather violent winter storms, but it quickly dies in warm water. Just like transplanting a polar bear to Hawaii, these species would not be able to survive in tropical waters. If sea temperature changes, some creatures can move to more comfortable locations, but others, like plants and invertebrates, die.

A decomposition table helps students recognize what types of trash enter the ocean, how long it takes trash to decompose, and how trash can affect sea life.

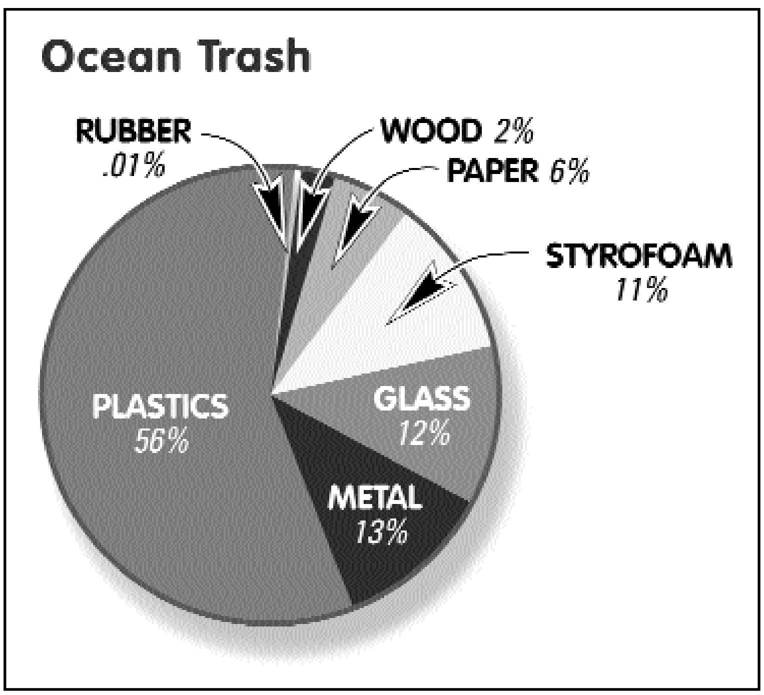
- **What are some human activities that may harm ocean health?** Over fishing, point and non-point source pollution, runoff from shore, anything contributing to global climate change, marine debris and plastics in the oceans including fishing line and “ghost nets.” Pass around the ghost net. **How could this hurt**

Onboard Marine Ecology Activity
continued

marine life? Fishermen use fishing nets to catch fish, sometimes these nets get caught on rocks or are left behind. These "ghost nets" continue to catch fish and other wildlife. These nets, and other plastics, are hard to break—have students grab hold of the net and try to break it. Show photos of wildlife caught in plastics. **What is marine debris?** Marine debris is any trash ending up in the ocean, from land or ships at sea. Plastics make up 56 percent of marine debris (show pie chart) and are especially devastating to marine life.

- **What happens when wildlife comes into contact with different types of marine debris?** Sometimes they mistake garbage for food. Sea turtles can mistake plastic bags for jellies and eat them. Sea birds such as pelicans dive for anything that resembles a shiny fish, such as candy wrappers or aluminum. Their stomachs fill up and they feel full, but they can't digest it or get nutrients from it and die from starvation. Use visual aids to help students understand what happens when waste is not properly disposed of, including photos of wildlife caught in six pack rings, and demonstrate how a plastic bag can be mistaken for food.

Over half of the trash in the ocean is plastic. Plastics threaten the ocean food web for hundreds of years, due to its slow rate of decomposition.



Wrap Up

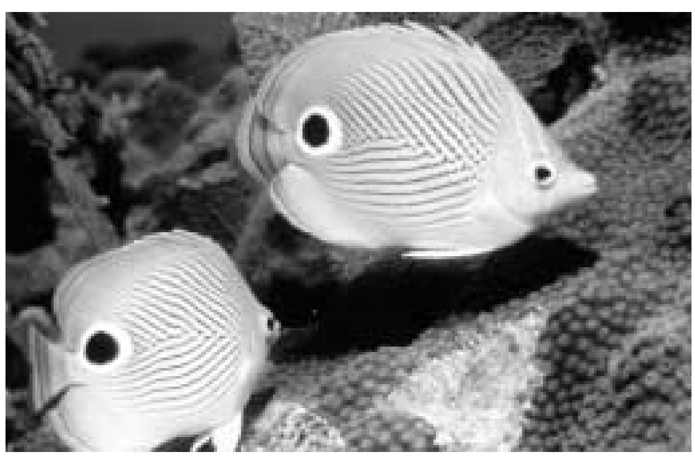
Marine ecosystems like kelp forests take millions of years to evolve. Species living in them are specialized to take advantage of unique environments. Understanding how these systems work, and how we can insure their survival, is essential as we make greater demands on natural systems. Marine sanctuaries were created to protect these ecological gems, though we must remain vigilant to reduce land-based pollution.

4 Marine Ecology station: Coral Reefs (On Board or Dockside)

20 minutes

Overview

The instructor reviews with students what they know about coral reefs, the coral reef habitat, importance of coral reefs, how they are formed, what they need to survive, and current threats to coral reef health. They conduct a hands-on activity to determine how much of a coral reef is alive. They then pass around a graphic of how corals reproduce, and speculate on how coral reefs can continue to grow and expand given existing environmental challenges. The idea of marine protected areas for coral reef health is discussed, and students hypothesize how large of an area needs to be protected to insure the health of a "typical" coral reef.



Two four-eyed butterfly fish. ©1987 Florida Keys National Marine Sanctuary Photo Contest entry.

DOCKSIDE MODIFICATION

This activity may be conducted on a dock with no modifications necessary.

The best place for first hand experiences with coral reefs is to dive or snorkel in a living reef habitat, a challenge for most classes but well worth it (work with a licensed instructor). To get up close to living corals without getting wet, visit an aquarium or zoo with a reef exhibit, or even a tropical fish store. See Appendix G for a list of living coral reef exhibits.

Activity Background

Overview. Instructor leads a discussion to help students review what they know about coral, coral reefs, and the coral reef habitat. Students discuss factors affecting coral reefs (trampling, collecting, over fishing, specimen collecting for aquarium trade, etc.). In an exercise to highlight how corals grow, students conduct a small group activity to estimate how much of the coral reef is alive (surface area). Students discuss the threats to the coral reef itself, and threats to species dependent upon coral reefs for survival. Students study coral polyp life cycles and use this information to predict how large a marine protected area needs to be to insure survival of coral reef habitats.

Objectives. Students will know how coral reef habitats are created, environmental requirements of corals, the coral polyp life cycle, what constitutes the living portion of the reef, what the impending dangers are to coral reefs, and necessary actions to protect coral reefs from destruction.

Introduction. Lead a discussion on coral reefs to both assess what students know, and to introduce new content. Understanding how coral grows will help them visualize how fragile this habitat is.

- **What is a reef?** Reefs are underwater structures, natural or manmade. People make artificial reefs to provide habitat for fish. Natural reefs are composed of living organisms, like corals, or of rock.
- **What is a coral reef?** Coral reefs are made from living corals. Although thousands of species inhabit coral reefs, only a fraction produce the limestone (calcium carbonate) that builds the reef. The most important reef building organisms are corals. Coral reefs can be made up of hundreds of species of coral.
- **What is coral?** There are two kinds of coral, hard or stony coral, and soft coral, also known as gorgonians. Soft corals don't build reefs. All the many shapes and sizes of corals are composed of individual polyps, a tiny animal that looks like an upside-down jelly with stinging tentacles to kill prey. In fact, corals are related to jellies, anemones, and other members of the cnidarian phylum (ny-DARE-ian). Reef-building coral polyps make stony cups of calcium carbonate as a base for themselves. As the polyps of a specific species grow and reproduce, they make up a coral colony in a specific shape—brain,

Science Concepts

- Coral reefs provide a unique habitat for thousands of species worldwide, in areas that are often nutrient deficient and unable to support life if not for the corals living there.
- Like rain forests, coral reefs have a large species biodiversity and are threatened habitats.
- Corals build their own habitat and have specific environmental requirements, primarily clear, warm, salty water.
- Many coral reefs surround and protect nearby islands from damage generated by heavy waves and hurricanes.
- Coral ground up by wave action and reef eating organisms like Parrotfish creates sandy beaches.
- Two basic groups of corals exist: soft coral and reef-building, or stony corals. Soft corals, or gorgonians, have polyps that don't build reefs, but have bits of limestone (calcium carbonate) within their soft

Science Concepts
continued

bodies and have a flexible skeleton that moves with the current. Reef-building coral polyps make hard, stony calcium carbonate skeletons under themselves. The fastest growing corals grow 3-4 inches a day, but most grow much slower.
- A coral reef may be comprised of many different species of corals.
- Coral polyps reproduce sexually and asexually.
- Coral polyps have a symbiotic algae associated with them, called zooxanthellae (zo-zan-THELL-ee), that make additional food for the polyps. The polyps cultivate their own internal "farms" of these algae, and provide the algae with a safe home and regular source of nitrogen and carbon dioxide created as waste products of coral polyps.
- To sustain this relationship, corals must live in shallow, clear water so sunlight can penetrate to support

Introduction, cont.

elkhorn, staghorn, flower, and so on. Reefs are formed when hundreds of hard coral colonies grow next to and on top of each other. During the day, the polyps stay within their calcium carbonate cups, and many think the reefs looks like inanimate rocks. But at night, the attached polyps emerge to spread out their tentacles and feed on microscopic plankton.

- **Why is coral special?** Coral makes its own home. It is about the only organism that creates its own habitat. The coral reefs that live in nutrient depleted water in warm tropical waters are able to survive because they have a life long plant partner called a zooxanthellae (zoh-zan-THEL-ee), an alga living in the tissue of the polyp. This symbiotic relationship provides habitat, light, and carbon dioxide from the coral to the plant, while the plant fixes energy from the sun and provides necessary sugars and nutrients to the coral to supplement what the corals get from plankton. Thousands of fish, invertebrates, and mammals depend upon this unique relationship of coral and their zooxanthellae to provide the reef habitat for them to survive. It is a highly specialized relationship, and many of the fish and invertebrates living on coral reefs have specialized relationships also. We'll explore these relationships in more detail in the classroom.
- **What types of creatures are found around coral?** Corals have many nooks and crannies for fish, octopus, sharks, brittle stars, and other invertebrates. Nurse sharks sleep in coral reef caves, and predators, including groupers, eels, sea turtles, and sharks, patrol the reef in search of their next meal. Some reef-dwellers feed on coral—fire worms crawl along the reef and eat polyps. Parrotfish bite off and grind up chunks of coral to get at the algae living there, and the crunched coral forms the sand around the reef.
- **How old is coral?** Individual polyps of smaller corals live less than one year, and polyps that form the larger corals can live from 5 to 6 years. But a coral reef can be hundreds of thousands of years old. The living coral builds upon the skeleton of the old coral, building new calcium carbonate cups to the existing structure. The Great Barrier Reef in Australia is thought to be 600,000 years old and is the size of California! Coral grows slowly—branching corals grow 3 to 4 inches per year but others grow more slowly—so a large coral head may be thousands of years old. Scientists take bores of corals to see how old they are, and count the growth rings just like an old tree.

Science Concepts
continued

the photosynthetic algae.

- Though some corals can get very large—the Great Barrier Reef in Australia is the size of California—only the top 1-3 mm on the surface of the reefs is living tissue. The Great Barrier Reef is thought to be 600,000 years old.
- Coral reefs have existed on earth for over 350 million years, but many of the world's reefs have been destroyed and up to 70% of the reefs may be lost within our lifetime if we don't take action now.

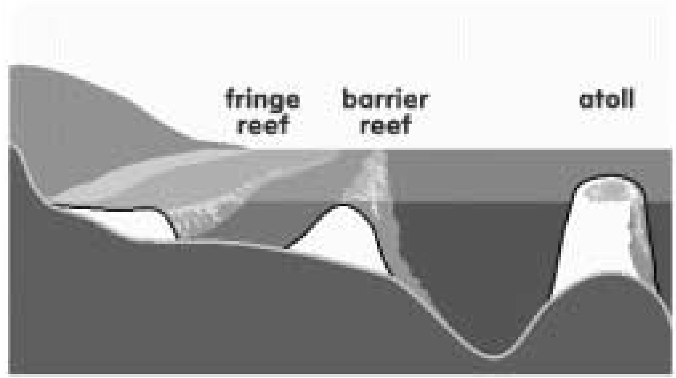
Expected Outcomes

- Define the term marine ecology
- Understand what a national marine sanctuary is and some of the reasons a coral reef would be designated a marine sanctuary
- Identify some activities that are acceptable in coral reef marine sanctuaries, and some that are not

Introduction, cont.

- **What does coral need to survive?** Reef-building coral has specific requirements—warm, clear, shallow water; lots of sun; and nutrient depleted ocean water so attached algae doesn't grow so fast that it covers the coral reef and shades the polyps. Coral needs clear, sediment free water that won't cover or clog up the tiny polyps. Corals are found in tropical waters especially around small islands and on top of underwater mountains, and some are on the eastern shores of continents. There are three kinds of coral reefs: fringing reefs (attached or directly adjacent to a coast: Indian Ocean, Kenya, Tanzania), barrier reefs (parallel to the coast, separated from land by a lagoon: the Great Barrier Reef of Australia), and atolls (at or near the surface of the sea when volcanic islands once surrounded by reefs sink below the surface: South Pacific Ocean, Bikini Atoll). Why don't they have coral in the ocean water off Oregon, or Maine? They do have coral—but it's soft coral, and with no tropical fish, of course, or any of the organisms you find associated with the tropical coral reefs.

Coral Reef Profiles



- **So corals are animals—do they have sex?** How do corals reproduce? Coral can reproduce asexually or sexually (show graphic of coral life cycle). Asexual reproduction occurs when a portion of living tissue buds off or when part of the colony is broken away from the parent colony. The polyp usually lands on the coral nearby. Sexual reproduction happens when egg and sperm combine to form larvae called planulae. Some of these larvae are planktonic and exist in the water column until they settle onto an appropriate substrate and grow into a single

PHYSICAL REQUIREMENTS OF CORAL REEFS

- **High light**—surface irradiance of 2,000 uE/sq m/s
- **High oxygen**—5.0 - 7.0 milligrams per liter
- **Low turbidity**—0.01 - 0.10 milligrams per liter
- **Low nutrients**—0.01 - 0.10uM [Nitrogen or Phosphorus]
- **Stable temperature**—18 - 30 degrees Celsius
- **Stable open ocean salinity**—33 - 36 parts per thousand

Expected Outcomes
continued

- Identify at least three of the living resources of the coral reefs
- Identify adaptations of organisms to coral reefs
- Know what constitutes the living portion of the coral reef
- Use a specific example of a plant and animal relationship in the sanctuary to describe how the marine environment supports itself and remains in balance (i.e., corals, zooxanthellae, fish)
- Identify three environmental parameters and how they affect coral reef health
- Describe how coral reefs are particularly sensitive to intentional and unintentional actions from humans
- Recognize the impact of land based pollution and sedimentation on coral reefs and their affect on the entire habitat
- List three reasons why marine protected areas are useful in preserving coral reef habitat, and why the size of a marine protected area can influence the degree of protection

Introduction, cont.

Coral Life Cycle

coral polyp. The single polyp will then grow into a colony. Coral spawning is a spectacular event and one means of sexual reproduction that occurs in the Florida Keys on an annual basis. Corals have been observed broadcasting their gametes into the water column five to eight days after the August full moon over the past four years. In the Caribbean, 40% of the corals are broadcast spawners, and 60% of them have eggs fertilized in the mother's mouth. The planulae crawl out of their mouth like an inchworm and settle close by.

- **Why should we be concerned about coral reefs?** What's happening to them? Coral reefs are being destroyed at an alarming rate. Many people want to visit a coral reef and see all the brightly colored fish and invertebrates that live there. It's better than a home aquarium. About 110,000 square miles of coral reefs exist in the world, covering less than one percent of our planet's sea floor—not much. Coral reefs support over twenty-five percent of all known marine species. As one of the most complex ecosystems on the planet, coral reefs are home to over 4,000 different species of fish, 700 species of coral and thousands of other plants and animals. The number of fishes living among coral reefs represents 30 percent of all the fish species that live in the oceans of the world! But coral reefs are in trouble; already 10 percent are lost and scientists say 70 percent of all corals on Earth will be killed off in 20 to 40 years unless people stop the destruction caused by pollution, sewage, erosion, over fishing and collecting, cyanide fishing, poorly planned tourism practices, and global warming. Coral reefs have existed on earth for over 350 million years but we are seeing their devastation at an unparalleled rate. Scientists are looking for natural chemicals found in unique coral reef species that may have

applications in pharmacology or cancer research. The resources hidden in coral reef species may be lost before they can even be identified.

Coral Life Cycle illustration used with permission from the Environmental Protection Agency (EPA), 1997. Coral Reefs: An English Compilation of Activities for Middle School Students. *EPA publication 160-B-97-900b. Environmental Protection Agency, Institute of Marine Sciences at the University of Southern Mississippi, National Sea Grant College Program of Puerto Rico.*

Materials

- Assorted pieces of stony coral. Dome-shaped pieces such as brain coral are best.
- Plastic wrap
- Sheet of paper with grid of one-inch squares (laminated, one for each small group of three)
- Graphic of typical coral life cycle

Note: images for photocopying are in Appendix H.

(Do not collect samples of "live" corals for this activity. The type of coral sample you choose will determine the difficulty of the task; easy with dome corals, difficult with irregular pieces.)

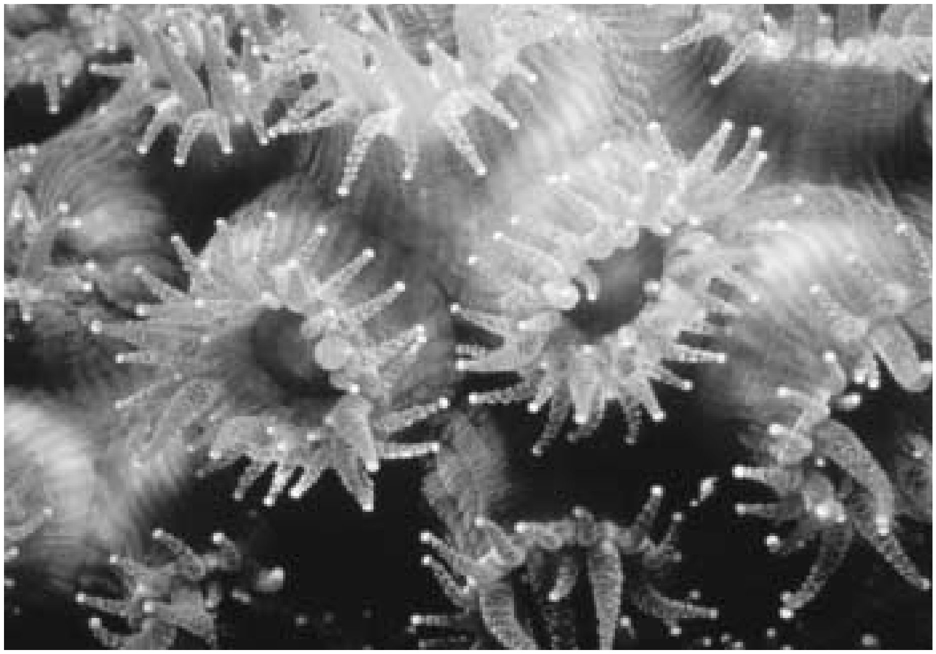
On Board Marine Ecology Activity—

Students calculate how much of the coral reef is alive.

- **What portion of coral is alive?** Divide the class into small groups of two or three. Give a sample of coral to each group. Hand a large enough square of plastic wrap to cover the piece of coral. Instruct students to cover the coral with the plastic wrap so it fits into all of the convolutions on the top of the coral piece using a single thickness of wrap. Cut off extra. Tell students that the thickness of the plastic wrap is about the same thickness of the living coral on the surface. Have students unwrap their coral and calculate the surface area in square inches. This surface area equals the entire living portion of the coral piece.
- **Lead a discussion** on the overall size of a coral reef versus the amount of living tissue that sustains it. What do you think happens to a coral reef if a boat drags its anchor over the top, or people walk on it? What about fishing practices that drag fishing nets over coral reefs? Or the practice of shooting cyanide into the coral reef to stun the fish so they float to the surface? What happens to the coral reef reefs when they put cyanide on them? Many people take chunks of living coral as souvenirs. Is this a wise practice? Why not? In some areas, people harvest coral reefs to use as building materials. Why is it so important to keep coral reefs intact? The coral reefs in the National Marine Sanctuary system are protected from these harmful practices, but the majority of coral reefs throughout the world are not.

Elkhorn coral and a white-spotted filefish. © Florida Keys National Marine Sanctuary.

Onboard Marine Ecology Activity
continued



Coral polyps build coral reefs.

- **Coral reproduction and marine protected areas.** One way corals are able to survive is by exporting their larvae to colonize new substrates. Though most larvae (planulae) end up as someone's food, given existing current conditions, some larvae can travel 600 to 700 miles to land on a new home. The average distance most larvae travel is 20 to 100 miles. Most planulae live in the water column for 2-3 weeks before they settle on hard substrate and grow into new adult colonies. A single tiny polyp can produce as many as 1,400 eggs. Multiply that by the millions of polyps that make up a coral reef, and the numbers are astounding. Discuss with students why, even with corals producing so many larvae, many coral reefs continue to decline. Lead into a discussion about marine protected areas and the need to not only protect existing habitats, but the adjacent areas also. Discuss the idea of a series of marine protected areas that would provide sufficient habitat for fish and invertebrate larvae carried by currents to colonize and spread into new areas, and the importance of ensuring larval recruitment of all species in keeping marine systems healthy. How large should these protected areas be?

Wrap Up

End this activity with a discussion of the coral reef in your sanctuary. Describe and display images of the species living there, and some of the specific threats and issues with your coral reef habitat. Discuss with students what they can do in their everyday lives that will help local coral reefs, be it using less fresh water to brush their teeth, carpooling or riding their bicycles, or talking with others about what they've learned about the fragility of coral reefs. Many people think coral reefs are made of rock and can't be harmed, or if they do disturb the reef it can recover easily. We know now that coral reef species exist in a delicate balance, and even if we as individuals don't do anything directly to harm the reefs, such as walk on them or collect pieces of the coral, they are still suffering from indirect impacts from our activities as humans. Encourage students to get involved—educate yourselves and others about the issues in your sanctuary, and work towards being a part of the solution.

Brain coral (right) and sea fan (left).

5 Navigation Station:
Shoreside

20 minutes

Overview

Students plot the bearings they took on board the boat onto a nautical chart. Using triangulation, along with the depth reading taken when on board, they determine where the ship was located when the group took the plankton tow. Students learn about other ways of navigation and the concepts behind them.

Students gather around the nautical chart and use math skills to locate their ship's position.

Science Concepts

- Navigation is the art and science of conducting a vessel safely from one location to another
- Nautical charts are road maps of the sea
- Lines of latitude and longitude are used to chart position on the earth
- Triangulation is the geometric process of determining a geographical position using two or more compass bearings. Traditionally, sailors have used this method to determine where they are located on the nautical chart, but new technology such as GPS uses satellites to determine a ship's location.

Activity Background

Overview. The Navigation Station takes place at a table with seating allowing the small group (about 10 students) to have a good view of the chart. The group gathers around and uses math skills in the hands-on process of plotting the bearings they took to locate where the boat was when they were taking plankton tows.

Objectives. Students use math skills to plot compass bearings on a nautical chart. They understand Earth can be divided into lines of latitude and longitude, and can find locations anywhere on Earth (land or water) by compass readings based on landmark navigation. Students can define two historical and one technological navigational methods.

Introduction.

- **What do you do if you get lost in the wilderness?** Some answers may be: get a map, look for landmarks, use a compass. Knowing where you are in relation to other places you know—this is called landmark navigation. There are other types of navigation, such as dead reckoning and celestial navigation, that don't rely on landmarks and can be used out at sea.
- Columbus and other explorers of his time used dead reckoning. With dead reckoning a navigator plots out a course beginning at one location, say, a port, and then measures out a course and distance from that point on the chart. He or she pricks the chart with a pin to mark the new position as the ship travels. These navigators needed to know their speed, distance, (speed times time equals distance) and direction (from the compass), and had an idea of where they wanted to go.
- Celestial navigation uses astronomical observations and a sextant, a hand-held device used to measure the angle of celestial bodies above the visible horizon. Polaris, the North Star, never moves in relation to the earth like the other planets do—it is always north in relation to Earth, no matter where you are on the planet. In ancient times, sailors would use a sextant to measure the altitude of Polaris from their home port. They were essentially measuring the latitude of their home port (show this on the globe).
  To return home after a long voyage, they would sail to the point where Polaris

Expected Outcomes

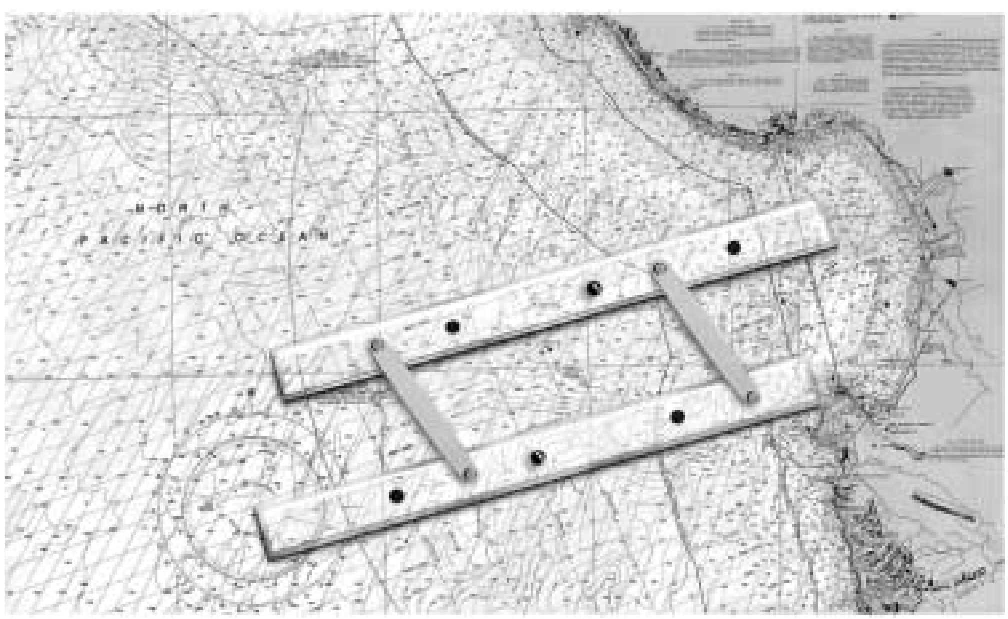
Students will:

- Understand the history of navigation and its importance in safely conveying ships and explorers across large expanses of ocean
- Use math skills to triangulate ship's position on a nautical chart
- Understand terms used in navigation (triangulate, fathoms, bearing, celestial navigation, GPS, line of position, etc.)
- Know how to read a nautical chart
- Understand the significance of knowing where you are on a nautical chart

Introduction, cont.

was at the altitude of home port, then turn west or east to "sail down the latitude," keeping Polaris at a constant altitude (show on globe).

- Today you took compass bearings on the boat from three landmarks for landmark navigation. Now you will transfer those numbers onto a nautical chart to determine where the boat was when you took those bearings, just like you can point to where your house is on a map (though a house doesn't move like a boat does!). This is how sailors navigate along the coast (coastal navigation) where they can still see landmarks. When out at sea, out of sight of land, sailors used to use either dead reckoning or celestial navigation. Now, pretty much everyone uses the global positioning system (GPS) based on computers and satellites.
- Show the students the nautical chart, and explain it is the same chart they saw on the screen of the GPS. Reinforce by pointing out obvious landmarks that they could see when on the boat (lighthouse, wharf, harbor, etc.).



Parallel rulers are used to "walk" the parallels from the compass to the landmark.

Materials

- Navigational chart *(laminated with a material that can withstand dry erase markers)*
- Parallel rulers
- Globe
- Three colors of non-permanent dry erase marker
- Data sheet from cruise

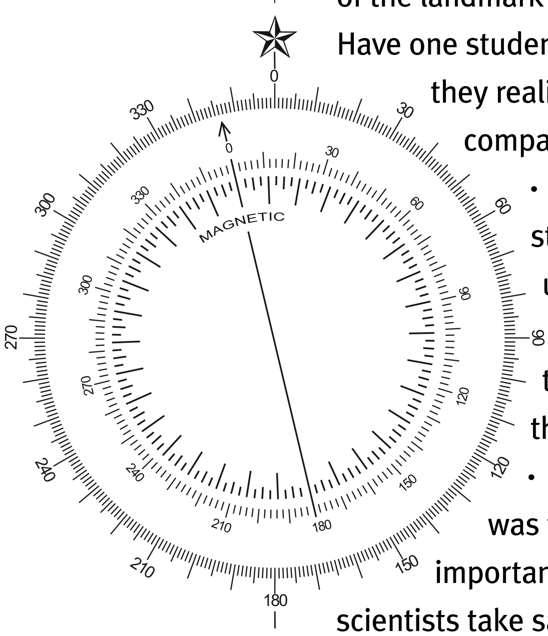
Shoreside Navigation Activity— Students participate in triangulation procedure

- It will take some effort to ensure each student has an opportunity to participate in this activity. They may take turns getting up from their seats to move around to be next to the instructor to mark on the chart or find landmarks, or the instructor can move around the group with the map. The map should be displayed on a horizontal, large table at a comfortable height for working up close. Students sit on stools.
- Have three students locate and mark on the chart the three landmarks their group used to get bearings. If your entire class has been broken into groups to go through the rotations (highly recommended), use a different color for each group when plotting their location. This way the entire group can see more clearly how the boat moves around the ocean – it can also help them to see some of the other aspects of navigation such as determining how fast the boat was going, figuring out the course, and so on.
- **You used a compass on the boat to take bearings. What did the compass show you?** The compass showed students where north was while they were out on the boat. Can you find where north is on this nautical chart? On nautical charts, the compass rose shows where north is, and all the other directions in terms of degrees from north, just like on your handheld compass. The compass rose is what sailors use to transfer compass bearing data onto the chart.
- Go over the use of the compass rose, and use the globe to show the students the difference between magnetic and true north. True north refers to the direction of the North Pole, where the lines of longitude begin. The magnetic North pole is constantly moving. It is currently located in the Arctic Ocean north of the Northwest Territories in Canada. Nautical charts are updated each year to reflect this change, or "declination", between true and magnetic north.
- **On the compass, what direction is "zero degrees?"** North is zero degrees. How many degrees does each line represent on the compass rose? On the compass rose each line represents one degree.
- Have a student read from the data sheet what the first bearing was. Have another student draw the bearing on the compass rose.
- **Does everyone know what parallel means?** What are some examples of parallel

Shore Side Navigation Activity
continued

lines? Parallel lines are two lines that will never cross. Examples include railroad tracks, how you hold your feet when you are ice or roller skating, or the front or back wheels on a car. Lines of latitude are parallel to each other. Introduce the parallel rulers. Show the students how to "walk" the parallels from the compass rose to the landmark.

- Sailors use triangulation to locate themselves in the water. Triangulation is the location of an unknown point by the formation of a triangle. Sailors use three compass bearings, plot them, and end up with a small triangle—the boat is located in that small triangle. First we'll get line of position (LOP) by establishing an angle using our first compass bearing, and finding the location of the landmark we took our bearing on and drawing a line of the same angle. Have one student draw a line of position using the parallel ruler, making sure they realize the line of position is parallel to the bearing drawn on the compass rose.



- Have another student plot the next bearing, then a different student plots the third bearing. In most cases, the group ends up with a small triangle plotted on the chart. Explain to them that this entire process they have just done is known as triangulation, and that the boat's location when they took those bearings was in the middle of this tiny (ideally) triangle.
- The location they just plotted is where a plankton sample was taken as they were taking their compass bearings. Why is it important to know where we were when we took this sample? When scientists take samples it is important to gather all data regarding the sample so they can make correlations and hypotheses based on data. Location, time of day, time of year, weather, all these factors play a role in why species are found at one time but not at another. Who knows, we could find the most northern member of a zooplankton species range and make scientific history in the record books!

Wrap Up

What you've done today, triangulate your location using compass bearings, has been done by sailors for thousands of years to navigate the seemingly endless seas. Now, most sailors use computers to do the same thing but practice these skills to understand the concept behind the technology. When at sea for research, recreation, commercial fishing and shipping, knowing where you are, and where the potential dangers are, can make the difference between life and death. Though most sailors now rely on technology to do the work, it is important to have a compass that doesn't rely on electricity in case of power failure, and to know how to navigate using a variety of methods.

6 Marine Biology station: Shoreside

20 minutes

Overview

The marine biology station is located in an indoor area housing a video microscope and large monitor for viewing plankton. This location is ideal for viewing plankton, engaging in a small group discussion of what plankton are, and their critical role in the ocean food chain. Students sit in a semicircle around the monitor, with an open space in the middle to play an optional food web game.

The instructor pipettes a sample from the collecting jar and places it in a depression slide on the microscope, then discusses features of the different groups of plankton and their role in the ocean food web. Students look at the monitor and identify what they see based on identification cards they hold in their hands, then play a short game based on plankton predator/ prey relationships.

Instructors can point out characteristics to help students identify plankton.

Science Concepts

- Ocean food webs, like terrestrial food webs, are based on light from the sun and contain producers and consumers.
- Life in the sea is possible only because of millions of microscopic plankton.
- Plankton ("wanderers") drift in the sea with little or no self-propulsion. Plankton include phytoplankton (plants), and zooplankton (animals).
- All plankton is either holoplankton or meroplankton. Holoplankton are small complete organisms spending their entire life free swimming. Meroplankton are free floating organisms for only a stage of their life cycle, usually the larval, egg, or spore stage.
- Larval stages of marine invertebrates often look nothing like their adult forms.

Activity Background

Overview. Students look at a plankton sample via a video-microscope and large screen monitor to identify species, then play a food web game demonstrating the interrelations of what they see. A whole group discussion relates what they see in the sample to ocean food web dynamics, and potential impacts on humans.

Objectives. Students understand the relationships of plankton to productivity in the oceans. They appreciate the many forms life in the sea can take, recognize the value of microscopic plankton, hypothesize about the food web connections between organisms they see on the slide, and distinguish ways in which microscopic marine organisms determine life in the sea. Students understand the concept and value of upwelling in the sanctuary, and the role upwelling plays in producing one of the richest marine habitats in the world. Students understand plankton are dependent upon water free of pollutants from land.

Introduction.

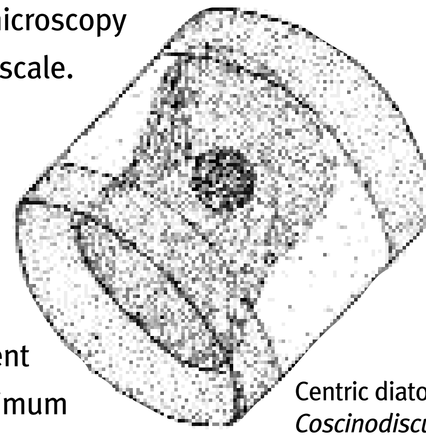
Who cares about plankton? You can't see it with your naked eye, you can't taste it or hear it, it's so small, why should we even bother learning about it? The world of plankton is a fascinating microcosm of life in the sea. Primary producers, predators, prey—all can be found in a single drop placed on a tiny microscope slide. Looking into the world of plankton is fascinating enough by itself, but its importance reaches much farther than as an isolated example of a food web; without plankton, life in the sea would be impossible. We'll look at our sample from the plankton tow on a microscope slide and try to find out who eats who, what all that debris is about, and learn about some dangerous plankton. **Plankton isn't only important to life in the sea—it's important to life on land, too. Does anyone know how?** Good answers can be about how the oceans provide food for people, and how phytoplankton contributes to global atmospheric oxygen and carbon dioxide. Phytoplankton produces almost 50 percent of the oxygen in Earth's atmosphere.

Science Concepts
continued

- Seasonal changes occur in the ocean Seasons in the ocean determine occurrence and abundance of plankton and the species depending upon them.
- Seasonal upwelling in the Monterey Bay produces upwelling of nutrient rich water, which stimulates phytoplankton to divide rapidly creating an "algal bloom." These upwelling events are responsible for the Monterey Bay sanctuary having one of the most productive marine ecosystems in the world.
- Zooplankton eat phytoplankton.
- Some zooplankton are predators, and some are grazers.
- Some phytoplankton produce naturally occurring toxins that are transferred up the food chain. Toxic diatoms can be found in plankton

Shoreside Marine Biology Activity—
Students observe prepared plankton slide and play simple food chain game.

- Assist students in the preparation of slides from the plankton sample. Describe the tools used for plankton viewing: microscope, slides, monitor, and identification cards. Describe microscopy and video microscopy with examples of size scale.
- As students observe and discuss as a group the structures and behaviors of plankton in the sample, the instructor may lead a discussion of plankton natural history and life cycles, including a description of what larvae are and how they can look very different from adult forms. Keep terminology to a minimum —it is far more valuable for students to make their own observations than to memorize terms in this short period of time.



Centric diatom
Coscinodiscus

- Relate plankton abundance to marine resources and the abundance and diversity of marine life in the sanctuary. Discuss food pyramids and how plankton supports populations of basking sharks and blue whales.
- If time, look at slides from the three different groups from today, or you may compare your sample today with a sample fixed from a different location. Compare the different sites and discuss reasons for differences. Why might the plankton samples be different? Time of day, wind speed, temperature, depth, and the sampling location all could affect what you find in your sample. Though plankton are drifters, they move around quite a bit yet are completely dependent on these natural environmental factors.
- **Even when dead, marine organisms provide food for someone else. Does anyone know how?** As plankton and fish die, they drift slowly down in the water column and provide food for organisms deeper down. "Marine snow" is the constant rain of natural detritus sinking through the water, food for scavengers living below the photic zone. Some deep water food chains depend upon detritus as a primary producer. Scientists have discovered tiny deep sea

Illustrations from A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae, Second Edition, *by DeBoyd L. Smith and Kevin B. Johnson.*

Science Concepts
continued

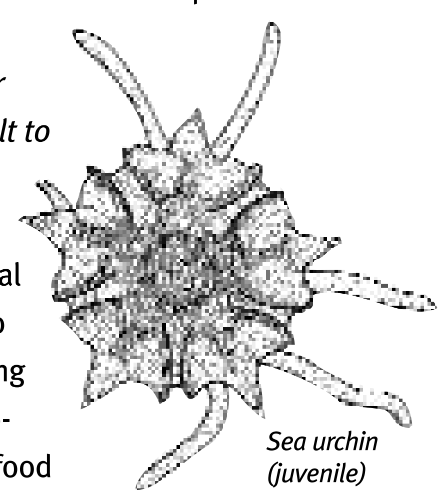
and in animals collected and dissected at the time of an algal bloom.

Expected Outcomes

Students will:
- Participate in analytical observation of marine plankton under a microscope and identify at least two species.
- Know the definition of phytoplankton and zooplankton and the cause of their diurnal patterns.
- Identify a simple plankton food chain with local species and recognize its importance in the sanctuary food web for resident and migrating species.
- Define meroplankton and holoplankton. Be able to identify one of each under a microscope.
- Understand the concept of seasonal

invertebrates, called larvaceans, that build huge mucus nets called "houses." These balloon-like structures collect marine snow and eat it.
- Look for molts and larval stages. Have students guess which larval stages belong to which adults.
- Have students look at shapes, such as symmetry and how it might relate to function. Look at spines, colors of organisms, eye size.
- **What are some non-plankton things in tows?** Fecal pellets, phytoplankton pieces (detritus). They all serve a function in the sea.
- Hand out two identification cards per student. Instructor keeps a master set containing all cards. Two activities can be played with the cards.

1. As the instructor moves slowly around the slide (or if time, have students take over moving the slide around) students look at the monitor and try to find an organism that is on one of their cards. Allow each student to take a turn. Once a student finds a match, instructor reads information on the back of the card while students read along. If no matches can be found, students hypothesize what organisms might eat each other in the sample (some look like animals, and others look like plants, while some are passive eaters and others pursue prey). Have students speculate about what all of the debris is on the slide. It likely is plankton feces, or poop! An incredible amount of plankton poop is in the ocean—it has nowhere else to go, and is a good food source for bacteria. Conduct a food web game: Each student will locate on the slide and identify one of the species on their card and note whether they are predator or prey (generally, zooplankton are predators or grazers, and phyto-plankton are prey). The students take on the persona of their species and match up predators with prey.
2. *(Note: some tows may contain **all** diatoms, or some other species, making this game difficult to play. In this case, have the discussion of why students think only one kind of plankton dominates in this tow.)* Inject an environmental variable and see what happens. It's an El Nino year, and a warm water current keeps upwelling from occurring, knocking out half of the phyto-plankton in our group. What happens up the food



Sea urchin (juvenile)

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Expected Outcomes
continued

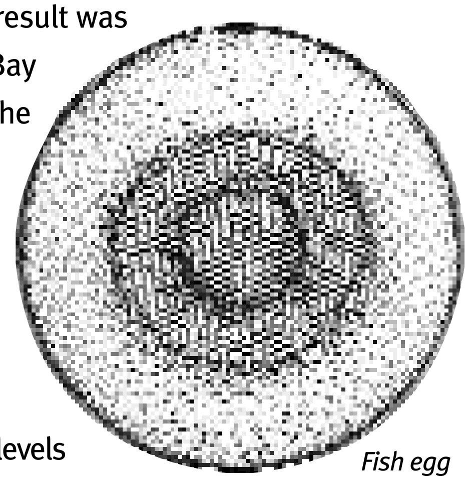
upwelling and its affect on plankton and the oceanic food web. Recognize how upwelling is responsible for the rich diversity and abundance of species in the sanctuary.
- Identify where and how the land/sea interface occurs, and how our actions on land can affect life in the sea.

Materials

- Specimens and data sheets from shipboard station
- Plankton identification cards for students, one master set for instructor
- Video-microscope and monitor
- Depression slides
- Pipette

Note: images for photocopying are in Appendix H.

chain? Predators may go hungry; larger species, those that don't fit on the slide such as anchovies and whales, may pass on the sanctuary and go elsewhere for food, further offshore, or north where food may be more plentiful.
- If time, discuss local phenomena and how these tiny, seemingly insignificant plankton can affect the entire structure of the food web and life in the sea. For example, in Monterey Bay, the 1997-98 El Niño event was the strongest recorded this century and caused profound declines in nutrient upwelling, phytoplankton growth, zooplankton productivity, and seabird and marine mammal abundance and reproduction. El Niño events bring a warm water current from South America. Why would warm water cause so much trouble? The warm water current suppresses upwelling of cold, nutrient rich water in the Monterey Bay, creating extremely high ocean temperatures and low levels of nutrients, chlorophyll, and primary production.
- When upwelling resumed late in 1998 the result was dense krill aggregations within Monterey Bay that attracted record numbers of whales. The following year, high levels of primary productivity in the spring of 1999 translated to high zooplankton abundance in early- and mid-summer. This followed the typical seasonal pattern of spring peaks in phytoplankton productivity, followed by summer peaks in zooplankton biomass. Zooplankton levels during the summer of 1999 were the highest recorded during the past three years, and they remained high throughout the fall. Would this have been a good year to go whale watching? Why?

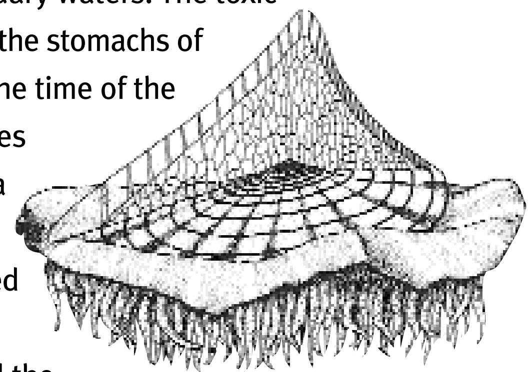


Fish egg

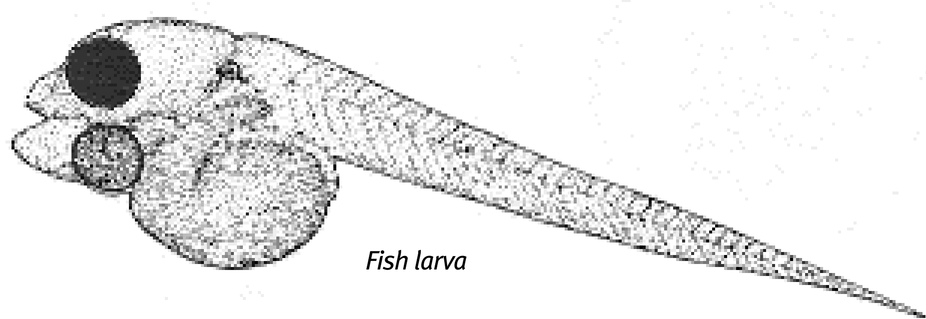
- Another example is harmful algal blooms (HABs). Look for harmful algal species (*Pseudo-nitzschia* primarily) and have students speculate about how the toxin is transferred through the food web.
- Periodically over the years, large numbers of California sea lions have washed up on shore very sick, dying, or acting drunk and wobbly. The cause was unknown. The first recorded episode of sea lion illness and mortality strongly linked to a documented bloom of *Pseudo-nitzschia australis* and associated poisoning by domoic acid occurred in Monterey Bay in 1998, when a bloom of

Shoreside Marine Biology Activity
continued

this pennate diatom occurred in sanctuary waters. The toxic diatoms were found in plankton and in the stomachs of anchovies collected and dissected at the time of the bloom. Marine mammal rescue agencies reported treating seventy stranded sea lions, forty-seven of which died. This may represent only a fraction of affected animals, as the victims were collected only from accessible beaches. How did the domoic acid, a neurotoxin, get to the sea lions? Sea lions eat anchovies, and the anchovies eat diatoms. The toxin is concentrated in anchovy tissue but the fish remain unaffected. Was this caused by pollution? Scientists are still trying figure out what triggers blooming algae to produce domoic acid. It is believed it is a naturally occurring toxin in the diatom, a chemical produced perhaps as a chemical “weapon” to keep predators from eating the phytoplankton. *Pseudo-nitzschia australis* always produces the toxin—it only becomes a problem when there is a massive algal bloom.



By-the-wind sailor



Fish larva

Illustrations from A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae, Second Edition, *by DeBoyd L. Smith and Kevin B. Johnson.*

Wrap Up

Movies such as “Free Willy” may win our hearts and encourage us to pledge to save the whales, but the true champions of the sea are those you can’t even see without a microscope. Life in the sea depends on its tiniest components. Keeping our oceans clean so plankton can do their important work making energy from the sun is one way we can all help keep our oceans productive and its inhabitants healthy for many years to come.

7 Marine Ecology Station: Kelp Forest (Shoreside)

20 minutes

Overview

After learning about the kelp forest ecosystem and open water food webs while onboard, students will have a better understanding of what lives below the sea surface. Now is an opportune time to expand awareness of how students' lives are intertwined with the oceans—how their actions can affect marine ecosystems. One example readily available (and a critical issue that students can do something about) is how our trash and other pollutants enter the ocean, and exactly how marine ecosystems are harmed by human activities.

Here we learn about kelp forest ecosystem dynamics and how land based pollution affects marine organisms and systems. Students identify local watersheds and how they contribute to sanctuary and ocean health. The class observes a working watershed model to learn about the water cycle, runoff, ground water, and how water pollution enters the marine environment via these systems.

Science Concepts

- Marine debris and pollution harm ocean communities in direct and indirect ways.
- Sea otters, a keystone species of kelp forests, are a case in point of a protected species whose habitat is at risk and the population remains in danger. Reasons have not been identified for sea otter decline and scientists continue to look for clues.
- The source of marine debris can be classified as either "ocean-based" or "land-based" depending on where it enters the water; 80% of pollution comes from land-based non-point sources.
- Ocean-based marine debris is waste disposed of in the ocean by ships, petroleum rigs, and platforms.
- Land-based debris is debris that blows, washes, or is discharged into the water from land. Contributors include recreational beach

Activity Background

Overview. Students review kelp forest dynamics learned during the shipboard ecology station and discuss how ocean pollution can affect kelp forests, in particular how pollution affects sea otters, a keystone species. Students conduct a hands-on experiment using a watershed model to display how pollutants can enter the oceans. They wrap up with a discussion of what individual actions they can take to prevent damage to ocean communities.

Objectives. Students will connect ocean health with their everyday activities by investigating how the kelp forest ecosystem is adversely impacted by human actions creating point and non-point source ocean pollution, including oil contamination. To do this, students experiment with a watershed model to observe how five pollutants enter the ocean by traveling through the environment via watersheds, ground water, storm drains, and wind. Students will identify the seven major watersheds feeding into the Monterey Bay sanctuary. Last, they will understand the importance of waste diversion methods and identify four things they can do to divert waste from landfills: reduce, reuse, recycle, and compost.

Introduction. Now they are more familiar with how a kelp forest ecosystem works, students can list what threats they think might harm kelp forests and other ocean communities in the sanctuary. Write their answers on a whiteboard. The list may include: storm drains carrying land based toxins to the sea, sewage outfalls, sedimentation, toxic waste, marine debris including plastics and fishing gear, over-fishing, cruise ship discharge, etc.

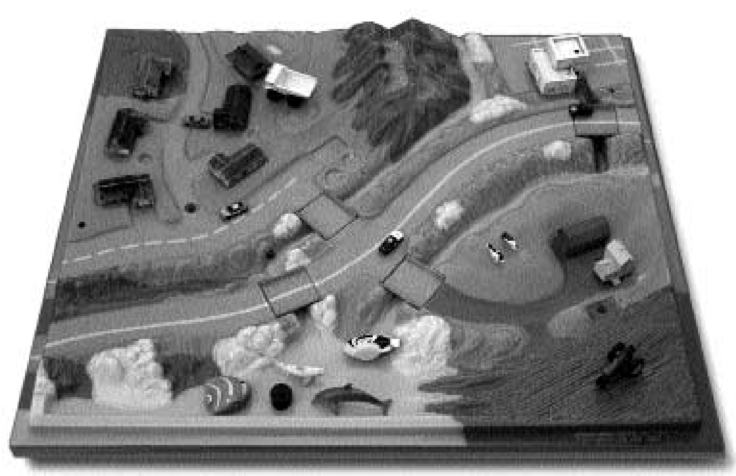
Have students brainstorm sources of land based debris and separate the debris into categories such as recyclables, compostables, and trash. Use the decomposition chart to clarify the meaning of biodegradable and non-biodegradable materials.

Science Concepts
continued

users, plastics manufacturers and transporters, inadequate sewage treatment operations, solid waste disposal activities, and illegal dumping.
- Land-based pollution has the potential to become marine debris. Garbage we produce in our homes and communities can reach the ocean via sewer systems, streams, and rivers.

Shoreside Marine Ecology Activity—
Students "dump" pollution on watershed model, and discuss affect of marine pollution on ocean habitats

- Begin the activity by asking what your students know about marine debris. **What is it, where does it come from, who is responsible for it, and how does it affect our lives? How does it affect marine life?** Put student answers on whiteboard for later reference.
- Review kelp forest ecology and the importance of sea otters in maintaining the natural balance of plants and animals. Information may include: Though California sea otters are protected from hunting, their population is still not growing, and some scientists think low levels of water pollution may be affecting their ability to reproduce. Sea otters eat sea urchins, and sea urchins eat kelp. If sea otters disappear, the kelp will be eaten by the sea urchins. If the kelp is eaten by sea urchins, the plants and animals depending upon the kelp forest will have a reduced or compromised habitat. It's just as though you cut down the redwood trees in a forest; the birds would have no where to nest, the understory ferns and shrubs would get sunburned, and the squirrels would have no place to forage and hide. Protecting a species must include protecting the habitat. In the ocean, the main way we can protect habitats is by keeping the water clean of debris and pollutants. But protecting the ocean from toxic inputs is a big job—as big as the ocean itself.
- Introduce the watershed model. **Can you find features on the model similar to where you live? How many of you live in a valley? Does anyone live near a harbor? Are there any streams or**



Watershed model

Expected Outcomes

Students will:

- Know what point and nonpoint pollution, marine debris, and biodegradable materials are.
- Understand, in coastal areas, all land-based pollution usually ends up in the sea.
- Determine how ocean pollution can affect kelp forests, in particular how pollution affects sea otters, a keystone species.
- Describe the water cycle.
- Describe how five pollutants enter the ocean by traveling through the environment via watersheds, ground water, storm drains, and wind.
- Define a watershed and its importance in fresh water and sea water quality.
- Identify three types of waste management: landfills, recycling programs, and composting.
- Identify biodegradable and non-biodegradable materials, and understand decomposition rates

lakes in your neighborhood? How about storm drains? The model has mountains, like the Santa Cruz mountains, rivers like the San Lorenzo river that drains a big valley, harbors and lakes, just like those found all over the land draining into the sanctuary. The sanctuary lies along 267 miles of the central California coast; eleven major watersheds drain into the sanctuary from both urban and rural areas. The sand and sediments the rivers bring with them make the broad, sandy beaches you see along the coast.

- Review the water cycle with students, and discuss how everything ends up in the oceans eventually, as shown by the following activity.
- One student sprinkles one color of powdered drink or cake sprinkles on the model in strategic areas to represent one type of waste in our environment. Soy sauce can represent oil pollution on the street. Have students take turns lightly sprinkling the "waste" in areas where it would occur, and lead a discussion on the types of waste, where it comes from, and speculate where it will go.
- Discuss the many ways pollution comes from the activities of people on land. It runs to the sea through storm drains, streams, and sewage treatment outfalls. Storm drains lead from streets and parking lots to waterways like rivers and creeks and eventually the ocean. If there is trash and pollution on the street, it washes into the storm drain when it rains.
- The drains in our homes lead to sewage treatment plants, or septic tanks if you live in the country. Sewage treatment plants are like big water cleaning factories that clean the dirty water and sewage from our homes. The process removes solids, exposes the remaining water to microbes for further breakdown of organics, adds chlorine, and then discharges to the ocean or a body of water. Old septic systems too close to rivers may drain accidentally directly into the river, causing pollution downstream.
- Much of our food comes from farms and orchards. Meat comes from animals raised on farms and most of our fruit and vegetables are grown on farms, too. Rain and irrigation water runs off the fields and into nearby streams, bringing with it chemicals many farmers add to their fields to help plants grow faster and be pest resistant. This runoff eventually makes it to the ocean.
- Most of our electricity comes from power plants burning fossil fuels; on the coast, oil is transported to the power plants by ships.
- Factories and power plants often add smoke and fumes to the air. Some factories and plants release sludge, leaking fuel, or boiling water. If disposed in the

Materials

- Decomposition chart (to be made with local materials)
- Topographic map of sanctuary with watersheds shaded in color and major rivers highlighted
- Watershed model
- Various colors of powdered drink mix
- Cake sprinkles
- Soy sauce
- Four spray bottles filled with water

Note: images for photocopying are in Appendix H.

ocean, chemicals, sediment, and water temperature differences can affect marine organisms.

- When we throw something away, our garbage goes to landfills, which are large holes in the ground where the garbage is usually buried. Wind can blow trash from the landfill into nearby streams, lakes, and the ocean. There is no "away!"
- When all the types of waste and pollution have been applied to the model, have students take turns simulating a rainstorm by spraying water onto the model with the spray bottles. The students observe how rainwater carries pollution and debris through storm drains and watersheds to the ocean.
- **Keeping the oceans clean is important for the animals living there, but it is important for life on land, too. Why?** Where does our oxygen come from? By day, plants take in CO_2 and give off oxygen. Approximately half of our oxygen comes from the plants on land and the other half comes from phyto-plankton and algae in the ocean. If the water has too much sediment or contains toxins harmful to plants, we stand to lose half our planet's ability to create oxygen!
- We release pollutants into our environment as part of our every day life. From the cars we drive (oil, brake pad dust, exhaust) to the food we eat, humans leave their mark on the land. Oil, chemicals from factories, runoff from golf courses and agriculture fields, runoff from city streets, mud, treated sewage, floating garbage, tires, cars, etc. are released into the sanctuary.
- **What is marine debris?** Marine debris is trash found in the ocean or along its shores.
- **Why is marine debris harmful?** Marine debris can be fatal to marine wildlife. Marine mammals, sea turtles, birds, and fish become entangled in plastic fishing line, plastic strapping bands, six-pack rings, and other plastic trash. Once entangled, they may become sick or weak, and even die. Certain marine animals can also mistake plastic debris for food and die. Sea turtles mistake plastic bags for jellies, and birds mistake small pieces of plastic for fish eggs.
- **What is source and nonpoint source pollution?** Land-based marine pollution can either be from a "point source" or a "non-point source." Point source pollution originates from a specific place like an oil refinery. Non-point source pollution, on the other hand, is contaminated runoff originating from an unknown location, often a variety of places. The soot, dust, oil, animal wastes, litter, silt, salt, and chemicals that constitute nonpoint source pollution often

Shoreside Marine Ecology Activity
continued

come from everyday activities such as fertilizing lawns, walking pets, changing motor oil, and driving. With each rainfall, pollutants from these activities are washed into storm drains, often leading directly to nearby bodies of water such as streams, rivers, and oceans. Non-point source pollution is 80 percent of land-based pollution in our oceans.

- **Can't a lot of trash decompose? How does so much end up in the ocean?** How long do you think an apple, a piece of paper, metal, or a plastic bag, takes to decompose? Refer to the decomposition chart on www.oneillseaodyssey.org web site, or make one of your own using real trash.

Wrap Up

Discuss with students how can we change our lifestyles to create less waste. We can implement the three R's (reduce, reuse, recycle) at home, at school, or anywhere we are. Write on the board: reduce, reuse, recycle, and have students brainstorm ways they can do this at home. Here are a few suggestions.

- Reduce: Use a sponge instead of paper towels; use metal utensils, a glass, or a plate instead of paper cups and plates and plastic utensils; write on both sides of paper; bring a canvas bag to the store instead of accepting a paper or plastic one; share items with friends and family; buy products with less packaging—one-third of our garbage is packaging! If you don't really need something, don't buy it!
- Reuse: Use a lunch sack for more than one day; bring lunch in reusable containers, reuse bags from the store, use containers such as shoe boxes and margarine tubs for storage, donate items to charities and thrift stores when you're done using them.
- Recycle: Newspapers, bottles, aluminum cans, car batteries, paint, automotive fluids, and plastic bottles. Complete the recycling loop and buy recycled products.

We can keep waste from going into landfills by putting it into soil building composters and using home and school recycling programs for nonbiodegradable trash. What kinds of things can go into a composter? Vegetable scraps from the kitchen, leaves, grass clippings and other plant materials can go into a composter. Suggest neighborhood and beach clean-up activities in which most waste is recycled or composted, and, better yet, is sure to not reach the ocean. Encourage alternative forms of transportation (ride a bike more often), reduce the amount of energy we use in our homes, and use alternative and cleaner sources of energy. Many beneficial products are produced from recycled materials, like decking from recycled plastic. Brainstorm with your students how they can approach adults in a helpful manner to modify some of their trash disposal habits. Ideas could include:

- Properly dispose of trash in garbage cans.
- Never dump chemicals on the ground or down storm drains because they may end up in the local stream, river, or bay.
- Walk pets in grassy areas or parks. Pet wastes on pavement can be carried into streams by storm water. Pick up after your pets.
- Do not pour chemicals down drains or toilets. They may not be removed in sewage treatment and can end up contaminating coastal waters. Use non-hazardous alternatives whenever possible.

Wrap Up, continued

- Cars need to be kept well maintained and free of leaks. Recycle used motor oil (most auto stores now collect used oil)
- Don't dispose of leaves or grass clippings in your storm drain. Remember, storm drains usually lead to a body of water, and excess nutrients are a type of pollution. Instead, try composting yard waste.
- Landscape your yard to prevent runoff. Use as few pesticides as possible. Visit a garden store to find "natural" (non-toxic) approaches to pest control and use organic gardening techniques.
- Conserve energy at home to reduce our need for fossil fuels.

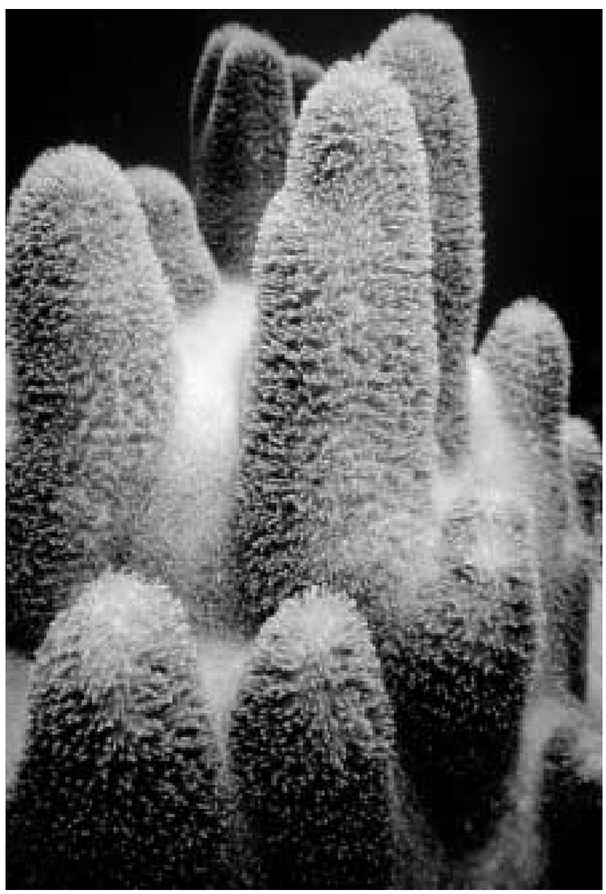
Now we know some of the common types of pollutants we put in the ocean every day. The next step is to look for alternatives to use in place of those pollutants. Using these alternatives, we can still have clean houses and luxuriant yards—and a healthy ocean!

8 Marine Ecology Station: Coral Reefs (Shoreside)

20 minutes

Overview

Included in this station are two activities: a quick coral reef health assessment and a watershed activity. Students first guess whether activities that harm coral reefs are natural or human induced, then look more closely at the how pollutants can enter coral reef habitats.



Corals come in all shapes and sizes. This is a pillar coral.

Science Concepts

- Marine debris and pollution harm ocean communities in direct and indirect ways.
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- Land-based debris is debris that blows, washes, or is discharged into the water from land. Contributors include recreational beach

Activity Background

Overview. Students conduct an activity where they investigate human and natural threats to coral reefs. They use the watershed activity from Station 7 to demonstrate how pollutants enter coral reef systems.

Objectives. To understand how fragile coral reefs are, students will investigate coral reef ecosystem dynamics and identify threats to the reef. Students learn how pollutants enter the ocean through watersheds, and brainstorm ways they can reduce marine pollution.

Introduction. Discuss with students the threats to coral reefs.
How are coral reefs doing? Not so well. Some coral reefs are being "loved to death" with too many visitors trampleling them, while others are being dynamited by fishermen to harvest the fish living there. Coral polyps are fragile and can be crushed by the slightest touch of a hand or swim fin, exposing the entire head to algal overgrowth or bacterial infection. Pristine water quality is critical for coral growth and reproduction and is in short supply in many areas. The coral reefs in the U.S. are more protected than those in the Philippines, but still, threats to all coral reefs are both local and global. Coral reefs have existed for millions of years, surviving many large and small changes in the environment. But now, natural (caused by nature) and human (caused by humans) threats to coral reefs are destroying miles and miles of coral reefs, and those remaining are showing signs of stress. Coral reefs in Florida are disappearing

Coral reefs supply habitat and food for many species. Here a green swims at the reef. © Florida Keys National Marine Sanctuary

Science Concepts
continued

users, plastics manufacturers and transporters, inadequate sewage treatment operations, solid waste disposal activities, and illegal dumping.

- Land-based pollution has the potential to become marine debris. Garbage we produce in our homes and communities can reach the ocean via sewer systems, streams, and rivers.
- Coral reefs are built by colonies of coral polyps creating calcium carbonate skeletons.
- Natural and human events can affect coral reef health.
- Coral reefs are in danger due to natural threats and human induced changes.

Introduction, cont.

from disease and coral bleaching when the water is no longer clear and clean, or as the water temperature rises. In other areas of the world, even more extensive damage is caused by people taking tropical fish for the aquarium trade, people taking pieces of coral as souvenirs or jewelry, fishing practices involving dynamite or cyanide, and a decrease in water quality due to pollution or sedimentation. Coral reef ecosystems are in great danger.

A recently released report funded by World Wildlife Fund warns degradation of coral reefs threatens the nearly $30 billion in net benefits these ecosystems provide each year in goods and services to world economies, including tourism, fisheries, and coastal protection. Coral reef systems, long known for their immense biological richness, are also crucially important for economic reasons, with a global asset value of nearly $800 billion.

Next, conduct this preassessment activity. On a laminated poster, list these eleven threats to coral reefs. For each threat, have a class wide discussion and let students guess which are natural threats (put an N by it) or human threats (put a H by it).

Expected Outcomes

Students will:

- Recognize coral reefs as a threatened ecosystem.
- Understand the difference between human and natural threats to coral reefs, and be able to name three of each.
- Learn how they can contribute to coral reef health by every day activities.
- Know what point and non-point pollution, marine debris, and biodegradable materials are.
- Understand, in coastal areas, all land-based pollution usually ends up in the sea.
- Describe the water cycle.

1. Hurricanes and tropical storms break and topple coral and batter fish.
2. Construction on or near the reef destroys coral or muddies the water, so corals smother.
3. Overfishing and destructive fishing methods (such as using dynamite, cyanide, bleach, fish traps, gill nets, or huge drift nets) decimate the reef ecosystem.
4. Too much rain dilutes the water, so it isn't salty enough for corals.
5. Marine debris or trash is dangerous to corals, birds, sea turtles, fish, and other marine animals.
6. Divers, snorkelers, and fishermen damage the reef with boats, anchors, and heavy gear. Even touching coral or standing on it can kill it.
7. Changes in currents can smother corals in mud/silt.
8. Collecting tropical fish, corals, and shells strips the reef of life.
9. Pollution from oil spills, chemical wastes, runoff from farms, factories, and golf courses, and sewage ruins the water quality that corals need.
10. Predators such as parrotfish, sponges, and sea urchins, eat corals or weaken it by boring into it.
11. Warmer water caused by global warming through the greenhouse effect may cause coral bleaching, a dangerous condition that occurs when corals lose their algae partners. Without these beneficial algae, corals die.

Next, ask students what they can do about helping coral reefs. Which are the threats we can do something about? What are some actions we could take today that might make a difference in the long-term survival of coral reefs?

Expected Outcomes
continued

- Describe how five pollutants enter the ocean by traveling through the environment via watersheds, ground water, storm drains, and wind.
- Define a watershed and its importance in fresh water and sea water quality.
- Identify three types of waste management: landfills, recycling programs, and composting.

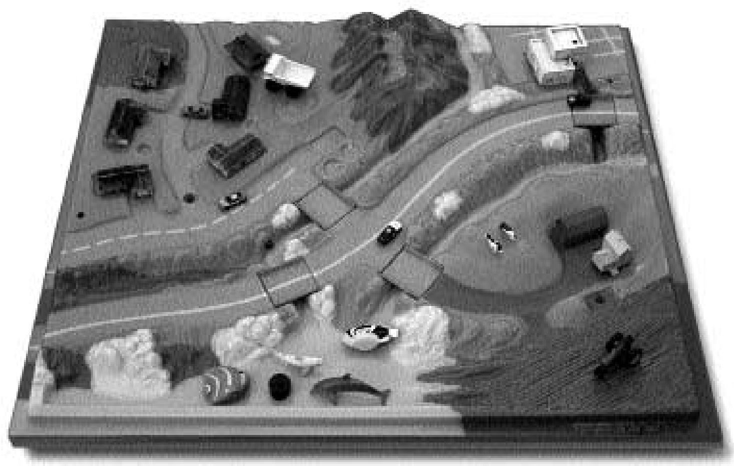
Materials

- Decomposition chart (to be made with local materials)
- Topographic map of sanctuary with watersheds shaded in color and major rivers highlighted
- Watershed model
- Various colors of powdered drink mix
- Cake sprinkles
- Soy sauce
- Four spray bottles filled with water

Note: images for photocopying are in Appendix H.

Shoreside Marine Ecology Activity—
Students "dump" pollution on watershed model, and discuss affect of marine pollution on ocean habitats

- Use the watershed activity as described in Station 7 (pages 59 to 61). Modify first paragraph to reflect coral reef habitats.



Watershed model

Wrap Up

Students return to their seats and discuss the simulation. What kinds of things did they learn about coral reefs? What is biodiversity and what is its relationship to coral reefs. Biodiversity refers to the variety of life on Earth. Coral reefs help sustain an incredible diversity of marine life. Depletion of one species can affect a myriad of other species because of the interconnections of organisms throughout the food web. Damage to the entire coral reef degrades the habitat many marine species, one-quarter of all species living in the ocean, depend upon.

Coral reefs provide food and protection for reef plants and animals, such as this sergeant major fish and angelfish. Credit: Florida Keys NMS staff.

Activity source
Introduction activity on Coral Reef Threats from The Incredible Coral Reef *by Toni Albert, ©1996 by Toni Albert. By permission of Trickle Creek Books, "Teaching Kids to Care for the Earth," 800-353-2791, www.TrickleCreekBooks.com*

Resources
Coral Reefs: An English Compilation of Activities for Middle School Students. *EPA Publication 160-B-97-9000. November 1997.*

The Virgin Islands Marine Advisory Service (VIMAS), a part of the University of Puerto Rico Sea Grant College Program, located within the Center for Marine and Environmental Studies (CMES) at the University of the Virgin Islands (UVI). (www.rps.uvi.edu/VIMAS)

World Wildlife Fund (www.www.panda.org)

Coral Reefs in the National Marine Sanctuary Program
Florida Keys National Marine Sanctuary (www.floridakeys.noaa.gov)
Fagatele Bay National Marine Sanctuary (www.fagatelebay.noaa.gov)
Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (www.hawaiireef.noaa.gov/)
Gray's Reef National Marine Sanctuary (www.graysreef.noaa.gov)
Flower Garden Bank National Marine Sanctuary (www.flowergarden.noaa.gov)

Appendix A.

National Science Content Standard Alignment

Stations 1 and 5: Navigation

Level K-4:

Physical Science, Content Standard B

Position and Motion of Objects

- The position of an object can be described by locating it relative to another object or the background.
- An object's motion can be described by tracing and measuring its position over time.

Light, Heat, Electricity, and Magnetism

- Magnets attract and repel each other and certain kinds of other materials.

Science and Technology, Content Standard E

Understandings about science and technology

- People have always had problems and invented tools and techniques (ways of doing something) to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.
- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

Levels 5-8:

Physical Science, Content Standard B

Motions and Forces

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
- If more than one forces acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion. (HOIST THE SAIL ACTIVITY)

Science and Technology, Content Standard E

Understandings about Science and Technology

- Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.

Stations 2 and 6: Marine Biology

Levels K-4:

Life Science, Content Standard C

The Characteristics of Organisms

- Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.

Life Cycles of Organisms

- Plant and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying. The details of this life cycle are different for different organisms.

Organisms and their Environments

- All animals depend on plants. Some animals eat plants for food. Other animals eat animals that eat the plants.
- An organism's patterns of behavior are related to the nature of that organism's environment, including the kinds and numbers of other organisms present, the availability of food and resources, and the physical characteristics of the environment. When the environment changes, some plants and animals survive and reproduce, and others die or move to new locations.

Levels 5-8:

Life Science, Content Standard C

Populations and Ecosystems

- A population consist of all individuals of a species that occur together at a given place and time. All populations living together and the physical factors with which they interact compose an ecosystem.

- Populations of organisms can be categorized by the function they serve in an ecosystem. Plants and some micro-organisms are producers—they make their own food. All animals, including humans, are consumers, which obtain food by eating other organisms. Decomposers, primarily bacteria and fungi, are consumers that use waste materials and dead organisms for food. Food webs identify the relationships among producers, consumers, and decomposers in an ecosystem.
- For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.
- The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of population in specific niches in the ecosystem.

Stations 3, 4 7, and 8: Marine Ecology

Level K-4:

Life Science, Content Standard C

The Characteristics of Organisms

- Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.

Organisms and their Environments

- All animals depend on plants. Some animals eat plants for food. Other animals eat animals that eat the plants.
- An organism's patterns of behavior are related to the nature of that organism's environment, including the kinds and numbers of other organisms present, the availability of food and resources, and the physical characteristics of the environment. When the environment changes, some plants and animals survive and reproduce, and others die or move to new locations.
- All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organism or other organisms, whereas others are beneficial.

- Humans depend on their natural and constructed environments. Humans change environments in ways that can be either beneficial or detrimental for themselves and other organisms.

Level K-4:

Science in Personal and Social Perspectives, Content Standard F

Types of Resources

- Resources are things that we get from the living and nonliving environments to meet the needs and wants of a population.
- Some resources are basic materials, such as air, water, and soil; some are produced from basic resources, such as food, fuel, and building materials; and some resources are nonmaterial, such as quiet places, beauty, security, and safety.

Changes in Environments

- Changes in environments can be natural or influenced by humans. Some changes are good, some are bad, and some are neither good nor bad. Pollution is a change in the environment that can influence the health, survival, or activities of organisms, including humans.

Level 5-8:

Life Science, Content Standard C

Populations and Ecosystems

- A population consists of all individuals of a species that occur together at a given place and time. All populations living together and the physical factors with which they interact compose an ecosystem.
- Populations of organisms can be categorized by the function they serve in an ecosystem. Plans and some micro-organisms are producers—they make their own food. All animals, including humans, are consumers, which obtain food by eating other organisms. Decomposers, primarily bacteria and fungi, are consumers that use waste materials and eat organisms for food. Food webs identify the relationships among producers, consumers, and decomposers in an ecosystem.
- For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.
- The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources and no disease or predators,

populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.

Diversity and Adaptations of Organisms

- Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lied on the earth no longer exist.

Level 5-8:

Science in Personal and Social Perspectives

Populations, Resources, and Environments

- Causes of environmental degradation and resource depletion vary from region to region and from country to country.

Natural Hazards

- Human activities also can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.
- Natural hazards can present personal and societal challenges because misidentifying the change or incorrectly estimating the rate and scale of change may result in either too little attention and significant human costs or too much cost for unneeded preventive measures.

Appendix B.
Equipment List

Navigation

Vessel-based equipment

1. Radar
2. Depth gauge
3. Global Positioning System
4. Knot meter

On Board and Dockside station

5. Hand bearing magnetic compasses. LED illuminated hand bearing compass with pistol grip, with 5 degree graduations and bold graduations every 15 degrees.
6. Global Positioning System. Submersible, compact, WAAS receiver for position accuracy to 3 meters, internal quad helix antenna. Includes built-in database of worldwide cities, tide tables and navigation aids such as lights, buoys, day markers, and lighthouses.

Classroom station

7. Standard parallel rules. Clear acrylic ruler with marine-grade aluminum arms and handles.
8. Navigational chart. Chart of local area where students took bearings and samples.

Navigation Supply Reference:

Most charter vessels are equipped with GPS, depth gauge, knot meter, and radar systems. All navigational supplies are available at West Marine (www.westmarine.com).

Marine Biology

On Board or Dockside

1. Plankton net. The plankton net is a 30 cm diameter ring with a three-point bridle and it is about 1 meter long. The collection jar is a 3 and one-half inch PVC collecting bucket with 110 micron mesh. The gauge of net is a 253 micron net, which is appropriate for obtaining a comprehensive sample in a short amount of time. For a longer tow, a larger gauge of net will allow you to sample larger types of mostly zooplankton.

2. Collecting containers. 50ml polypropylene centrifuge tubes with base and screw cap.
3. Dropper. Plastic dropper, 1ml, for collecting plankton sample for slide.
4. Salinity refractometer. Hand-held with specific gravity and salinity scales, designed for rapid, accurate salinity determinations requiring only a drop of sample. Automatic temperature compensation. Resolution 0 to 100 ppt.
5. Oceanographic secchi disc. White on one side, black on the other, 200mm diameter, white acrylic with stainless steel eye bolt and reversible weight, sounding line kit.
6. pH Meter. Waterproof pH tester, range -1.0 to 15.0 pH, resolution: 0.1 pH, accuracy: + or - 0.1 pH, calibration 3 points (pH 4.0; 7.0 and 10.0), operating temperature: 0 to 50 degrees C (32 to 122 degrees F).

Classroom
7. Compound microscope with digital camera. Dual viewing head compound microscope, mechanical stage, WF10x eyepiece. Mounted on the microscope is a digital signal processing color video camera with 480-line resolution, advanced light control functions, a selectable aperture level, and auto gain control. Signal to noise ration of 50dB.
8. Zoom stereomicroscope. This microscope uses less magnification and a wider-angle lens and allows the examination of larger animals and plants. Magnification, 10X – 40X; field of view 22mm, 3.4mm; 45% inclined binocular head; side mounted zoom controls. The dissecting microscope is also connected to the digital camera and monitor.

Marine Biology Supply Reference:
Many of the laboratory supplies can be found in a number of catalogs. The plankton net, salinity refractometer, pH tester, collecting containers, microscope and camera, and secchi disc, are available from:

- Nasco Science Catalogue (www.eNASCO.com)
- Wildlife Supply Company (www.wildco.com)
- Carolina Biological Supply Company (www.carolina.com)

Collecting tubes: Elkay Precision Laboratory   800 Boston Turnpike Shrewsburg, MA
Plankton nets may also be purchased from:

- Forestry Suppliers, Inc. (www.forestry-suppliers.com)

Marine Ecology

Shipboard or dockside

1. Sea Otter pelt. The sea otter pelt was donated by the Monterey Bay Aquarium.
2. Kelp sample. A small sample of Macrocystis is collected daily.
3. Products that contain algin. Products that contain algin (kelp extract) can be found in any grocery store. Any item that contains kelp extract will have the word algin or alginate in the list of ingredients. Place them in a translucent plastic container to show to students without risk of dropping into ocean.
4. Portion of ghost net. This net was removed from around the necks of two young elephant seals in 1997 by the Marine Mammal Rescue Center.
5. Decomposition Chart. This chart was made O'Neill Sea Odyssey staff.

Classroom

6. Watershed model. Waterproof, plastic, three-dimensional model.

Ecology Supply Reference:

O'Neill Sea Odyssey staff creates many ecology supplies such as the decomposition chart. Information on decomposition rates and local recycling procedures can be obtained by calling local landfill/recycling center. When dealing with waste displays, care must always be taken to avoid accidental littering while at sea. Any waste chart should be waterproof and windproof to avoid the possibility of trash blowing overboard.

The kelp sample is collected daily from the boat. Keep a bucket and a rope handy for kelp and water samples. The ghost net was donated to our program. Often fragments of nets can be found washed up on the beach after storms. Frequently, fishermen tear and repair their nets; pieces of damaged nets can be obtained by calling a local fishing company. Marine laboratories often have sculls, skeletons or preserved remains of local wildlife available for study.

The watershed model was purchased from Enviroscape Educational Models (www.enviroscapes.com). Enviroscape makes several different models to teach about watershed pollution issues.

Appendix C.
Glossary

ACID – A chemical compound, usually a liquid capable of transferring a hydrogen ion in solution. Any substance with a pH value of less than 7.

ADAPTATION– Changes occuring in a species over time so it adjusts to a new or changed environment. Anything helping an animal/plant to survive in its environment (special body parts, behaviors or coloration).

AQUATIC ORGANISMS– Plants or animals living in water.

ASTRONOMY– The study of objects outside the earth’s atmosphere such as celestial bodies and the solar system.

BASE– Any chemical capable of accepting or receiving a hydrogen ion from another substance. Any substance with a pH of more than 7.

BENTHIC– Any of a diverse group of aquatic plants and animals that lives on the bottom of marine and fresh bodies of water. The presence or absence of certain benthic organisms can be used as an indicator of water quality.

BIOACCUMULATION– The accumulation of a substance, such as a toxic chemical, in various tissues of a living organism.

BIOLOGY– The science of life and of living organisms.

BLOOM– A sudden increase in the number of phytoplankton often following a flood of nutrients from heavy rain or a string of sunny days.

BOW– The front section of a ship or boat.

BUOY– An anchored float marking a position or a hazard on the water, or for use as a mooring.

CATAMARAN – A boat with two parallel hulls.

CHLOROPHYLL – The pigment used in photosynthesis to capture light energy and convert it to chemical energy.

CONDENSATION – The process of water vapor becoming a liquid such as dew, fog or rain.

CONSUMER – An organism that ingests other organisms or organic matter in a food chain.

COURSE – The direction in which a boat is steered.

DYNOFLAGELLATE – A type of plankton with two long whip-like organs called flagella used for locomotion.

ECHOLOCATION – An auditory feedback mechanism in bats, porpoises, seals and certain other animals whereby reflected ultrasonic sounds are used to find objects or prey.

ECOLOGY – the science of the relationships between organisms and their environments.

ECOSYSTEM – An interacting community of animals and plants depending upon each other and their environment for survival.

ELEMENT – Any of the four substances, air, water, fire, and earth formerly believed to compose the physical universe, usually used to describe weather conditions.

ENDANGERED – Threatened with extinction.

ENVIRONMENT – All the living and nonliving things with which an organism interacts.

FATHOM – A unit of measurement used for depth: one fathom is six feet.

GEOGRAPHIC LOCATION – A specific place on Earth. The identification of a specific area in relation to what lies around it.

HABITAT – The physical place where an organism lives.

HELM – The steering gear of a ship, especially the tiller or wheel and the surrounding area.

HERBIVOROUS – An animal feeding on plants.

HOLOPLANKTON – Plankton remaining free-swimming through all stages of its life cycle.

HYPOTHERMIA – The condition of reduced body temperature, which can result in death.

KELP – The common name for large brown seaweed.

KEYSTONE ANIMAL – A species directly affecting the ecosystem in which they live. Scientists can use a keystone animal as an indicator of environmental health.

KNOT – Nautical miles per hour.

LATITUDE – The distance north or south of the equator measured and expressed in degrees.

LIGHTHOUSE – A structure with a powerful light giving a continuous or intermittent signal to navigators.

LONGITUDE – The distance in degrees east or west of the meridian at Greenwich, England.

MEROPLANKTON – Any of various organisms spending part of their life cycle, usually the larval or egg stages, as plankton.

MICROSCOPIC – Anything invisible to the naked eye and can only be seen with the aid of a microscope.

MIGRATE – The process of moving from one region to another with the change of seasons or climate.

MONTEREY BAY NATIONAL MARINE SANCTUARY – A federally protected marine area offshore California's central coast. Stretching from Marin to Cambria, the MBNMS encompasses a shoreline length of 276 miles, and 5,322 square miles of ocean, extending an average distance of 30 miles from shore. At it's deepest point, the MBNMS reaches down 10,663 feet (more than two miles).

MONTEREY SUBMARINE CANYON – A submarine canyon located in the Monterey Bay over 15,000 feet in depth.

NAUTICAL MILE – One minute of latitude; approximately 6,076 feet – about 1/8 longer than the statute mile of 5,280 feet.

NAVIGATION – The art and science of conducting a vessel safely from one point to another.

NEUTRAL – Neither acid or basic. Fresh water is neutral with a pH of 7.

ORGANISM – Any form of animal or plant life.

PARALLEL – Two lines extending in the same direction and angle and never meeting.

PELAGIC – Having to do with the open ocean or open water; away from the shore or coastline. A pelagic animal swims freely in the open ocean.

PLANKTON – Small, usually microscopic plants (phytoplankton) and animals (zooplankton) in aquatic ecosystems.

PHOTOSYNTHESIS – Process in which light energy is converted to chemical energy by plants using water and carbon dioxide; results in the production of oxygen and carbohydrates such as sugar and starches.

PHYTOPLANKTON – Microscopic, single celled, drifting photosynthesizers not able to swim against currents.

PORT – The left side of a ship or boat.

PRESSURE – A type of stress which is exerted evenly in all directions.

PRODUCER – A photosynthetic green plant or chemosynthetic bacterium, constituting the first trophic level in a food chain.

RED TIDE – A bloom of phytoplankton, usually dynoflagellates.

REFRACTOMETER – An instrument used to measure the index of refraction of water in order to determine salinity.

RUNOFF – The part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

SALINITY – The relative concentration of dissolved salts, usually sodium chloride (salt), in given water.

SATELLITE – A celestial body orbiting another of a larger size, or a manufactured object intended to orbit the earth, moon, or another celestial body.

SECCHI DISK – A disk used to measure the visibility of water.

SEXTANT – A navigational tool used to determine position by measuring the angle of celestial bodies above the horizon.

SOUNDING – A measure of the depth of water.

SPECIES – A reproductively isolated group of interbreeding organisms.

STARBOARD – The right side of a ship or boat.

STERN – The rear part of a ship or boat.

SURFACE TEMPERATURE – The temperature of the layer of seawater nearest the atmosphere.

SURFACE TOW – The process of obtaining a sample of plankton by towing a plankton net along the surface of the water rather than dropping it down to the bottom of the ocean and pulling it up to the surface.

TEMPERATE ZONE – An area of the earth mid way between tropical and cold, usually found in the mid latitudes. An area where the weather patterns are identified by a lack of extreme temperatures.

TRIANGULATION – The geometric process of determining a geographical position using two or more compass bearings.

UPWELLING – Movement of water and nutrients from deep water towards the surface; an important source of nutrients for phytoplankton growth.

VELOCITY – Rate of speed.

ZOOPLANKTON – Animal plankton ranging from microscopic larval sea stars to huge jellyfish.

Appendix D.

National Marine Sanctuary Program Description

In 1972, exactly one hundred years after the first national park was created, the nation made a similar commitment to preserving its marine treasures by establishing the National Marine Sanctuary Program. Since then, thirteen national marine sanctuaries, representing a wide variety of ocean environments, have been designated.

Today, our marine sanctuaries encompass deep ocean gardens, nearshore coral reefs, whale migration corridors, deep sea canyons, and even underwater archeological sites. They range in size from one-quarter square mile in Fagatele Bay, American Samoa to over 5,300 square miles in Monterey Bay, California, one of the largest marine protected areas in the world. Together these sanctuaries protect nearly 18,000 square miles of ocean waters and habitats, an area nearly the size of Vermont and New Hampshire combined. While some activities are regulated or prohibited in sanctuaries to protect resources, multiple uses such as recreation, commercial fishing, and shipping, are encouraged. Research, educational, and outreach activities are other major components in each sanctuary's program of resource protection. To learn more about our thirteen national marine sanctuaries, visit http://www.sanctuaries.noaa.gov/oms/oms.html.

Appendix E.

Additional Resources

Internet Resources for Ocean Education

www.vims.edu/bridge

BRIDGE Ocean Sciences Teacher Resource Center—Lesson plans, professional development, student opportunities, on-line publications, marine literature,national projects, regional resources, aquariums, research institutions, agencies, organizations,information centers.

www.sea.edu/default.htm

Woods Hole Sea Education Association—An excellent resource with many hands-on activities for grades k-12 on nautical science, oceanography, physical oceanography, marine biology, and marine ecology.

www.swfsc.ucsd.edu/bibliography/GUIDE.htm.

NOAA's Resource Guide for Teachers of Marine Science.

www.bigelow.org

The Bigelow Lab for Ocean Science in Maine is a private, non-profit research center. This web site has great information on food webs and conservation.

www.gma.org

Gulf of Maine Aquarium site—Look for lots of kid oriented links with great information on individual animals. Also includes a section on learning from satellites.

www.marine-ed.org

Bridge Ocean Science Education Center site in conjunction with National Marine Educators Association—This is a great resource for teachers who are interested in structuring a marine biology curriculum.

www.montereybayaquarium.org

Monterey Bay Aquarium—Visiting this site is a great introduction to the creatures and habitats of the Monterey Bay.

www.nationalgeographic.com

National Geographic has a wonderful kids section focused on ecology news.

www.nhptv.org/
The New Hampshire public television site has a 16 part natural science series for grades 3-6.

www.oceanlink.island.net
The Bamfield Marine Station in British Columbia has set up their entire web site for kids. Check out the 'Ask a Scientist' section.

www.oceanrx.org
Rediagnosing the Oceans. A Film by Randy Olson and Jeremy Jackson. Video viewable on this website.

www.ucsc.edu/seymourcenter/
The Seymour Center in Santa Cruz offers tours of their marine lab to school groups. If you can' t make it to the lab in person, this web site is the next best thing.

www.websites.noaa.gov
The National Oceanographic and Atmospheric Administration web site has information in all oceanographic areas. You can even check this web site to get a local weather forecast before attending the O' Neill Sea Odyssey Program.

www.mbari.org
MBARI is the research center for the Monterey Bay Aquarium. This site contains updated information from deep-sea explorations and other areas of marine biology research. Teachers will find valuable seminars and educational opportunities in the web site calendar.

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Videos

Rediagnosing the Oceans. A Film by Randy Olson and Jeremy Jackson. http://oceanrx.org/ This video is available for viewing on the website.

In many marine environments, continuing problems have caused scientists to question their initial diagnosis. Rediagnosing the Oceans presents a new way to address the human impact on the marine biomes. In addition to addressing the current identified changes in species population and range, this approach includes an historical perspective in the rediagnosis of the problem. Using video case studies, the Scripps Institution of Oceanography clearly explains why focusing simply on minimizing human impact will not fix the imbalance in marine environments. For example, New England kelp beds have disappeared because of the increase in sea urchins who feed on the kelp. At first, scientists focused on the over-fishing of lobster as the cause of the sea urchin population explosion. However, the lobsters are still plentiful yet sea urchins populations continue to grow. Rediagnosis, drawing upon historical information and looking at the big picture including other predatory species, indicates it is the over-fishing of cod and other predatory fish, not lobster, that has contributed to the increase in sea urchins and subsequent decline in kelp.

Appendix F.
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Appendix G.

Coral reef Exhibits

Note: This is a partial list.

Aquarium of the Americas
New Orleans, LA 70130
504 861-2537

Henry Doorly Zoo
Omaha, NE 68107
402 733-8401

John C. Shedd Aquarium
Chicago, IL 60605
312 939-2426

Key West Aquarium
Key West, FL 33040
305 296-2051

Marineland of Florida
St. Augustine, FL 32086
904 461-1111

Marine World Africa USA
Vallejo, CA 94589
707 644-4000

Miami Seaquarium
Key Biscayne, FL 33149
305 365-2519

Mystic Marinelife Aquarium
Mystic, CT 06355
203 536-3323

National Aquarium
Baltimore, MD 21202
410 576-8685

New England Aquarium
Boston, MA 02110
617 973-5200

Quebec Aquarium
Quebec, Canada G1W 4S3
418 649-5264

Sea Life Park Hawaii
Waimanalo, HI 96795
808 259-8909

Seattle Aquarium
Seattle, WA 98181
206 386-4320

Sea World
San Diego, CA 92109
619 226-3939

Sea World of Florida
Orlando, FL 32821
407 351-3600

Sea World of Ohio
Aurora, OH 44202
216 562-8101

Steinhart Aquarium
San Francisco, CA
415 750-7145

Stephen Birch Aquarium, Scripps
Institution of Oceanography
La Jolla, CA 92037
619 534-FISH

The Living Seas
EPCOT Center, Disney World
Orlando, FL 32830
407 560-7688

The National Aquarium of
Washington D.C.
Dept. of Commerce Building
Washington, D.C. 20230
(202) 482-2825

Vancouver Aquarium
Vancouver, British Columbia,
Canada V6B 3X8
604 268-9900

Waikiki Aquarium
Honolulu HI 96815
808 923-9741

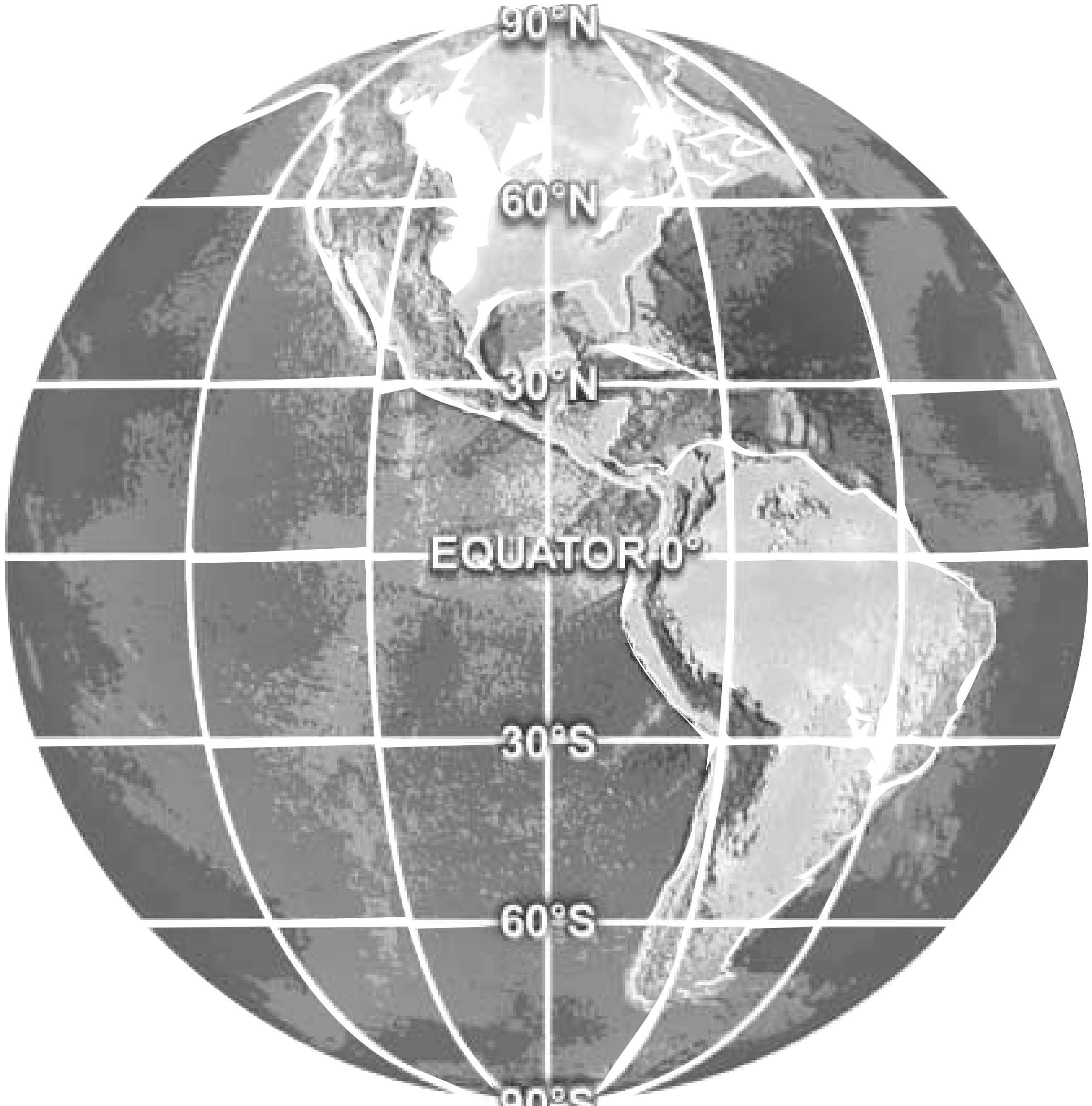
From: The Incredible Coral Reef, by Toni Albert, © 1996. By permission of Trickle Creek Books, "Teaching Kids to Care for the Earth," 800-353-2791, www. TrickleCreek Books.com.

Appendix H.
Images for Photocopying

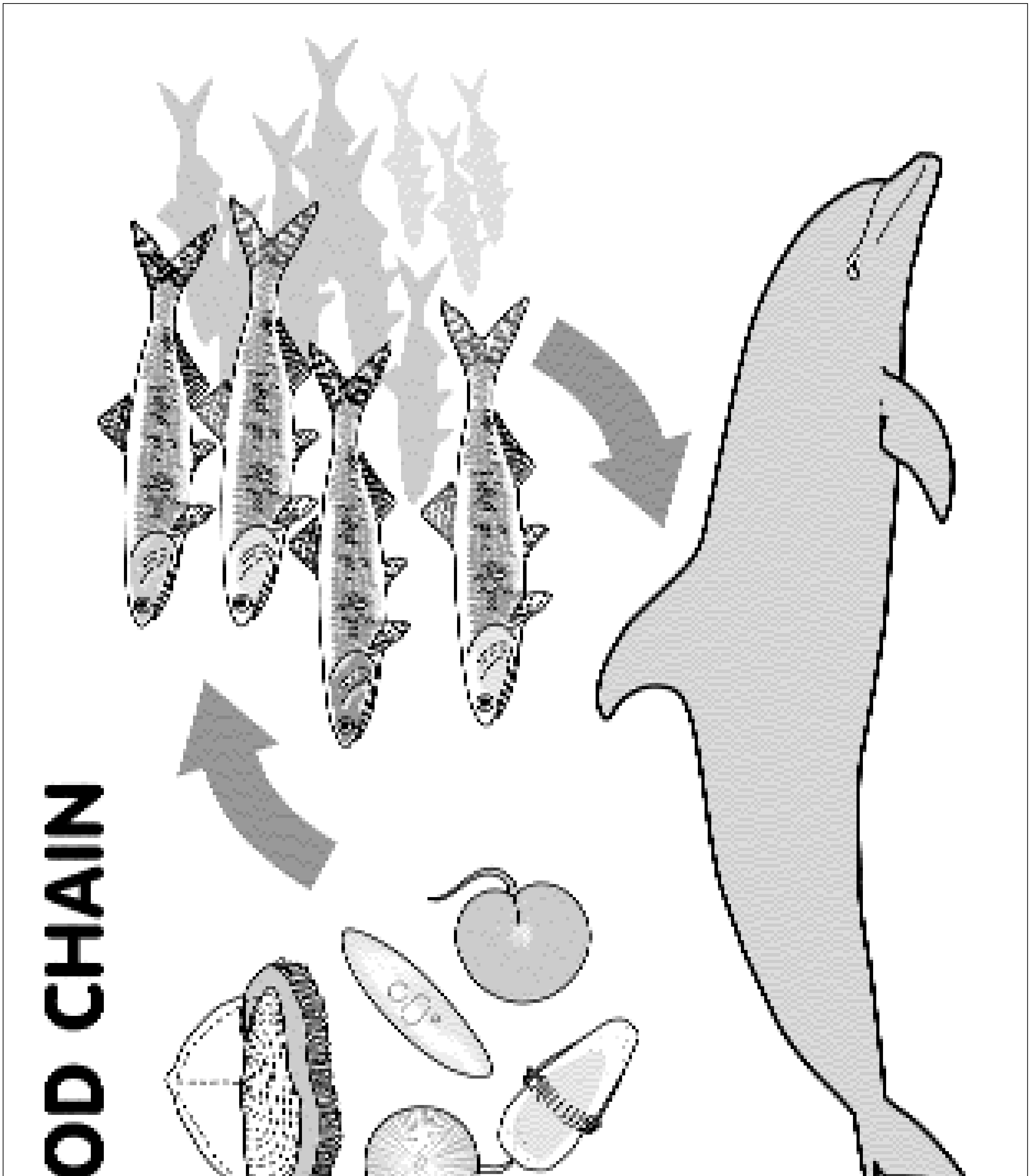
The following images are provided for use in the activities.

Station 1:	Latitude and Longitude
Station 2:	Food chain
Station 3:	Kelp Forest Illustration Kelp Forest food web Kelp Bed photo
Station 4:	Life Cycle of Coral
Station 6:	Plankton Cards
Station 7:	Sanctuary Watersheds

Station 1



Station 2

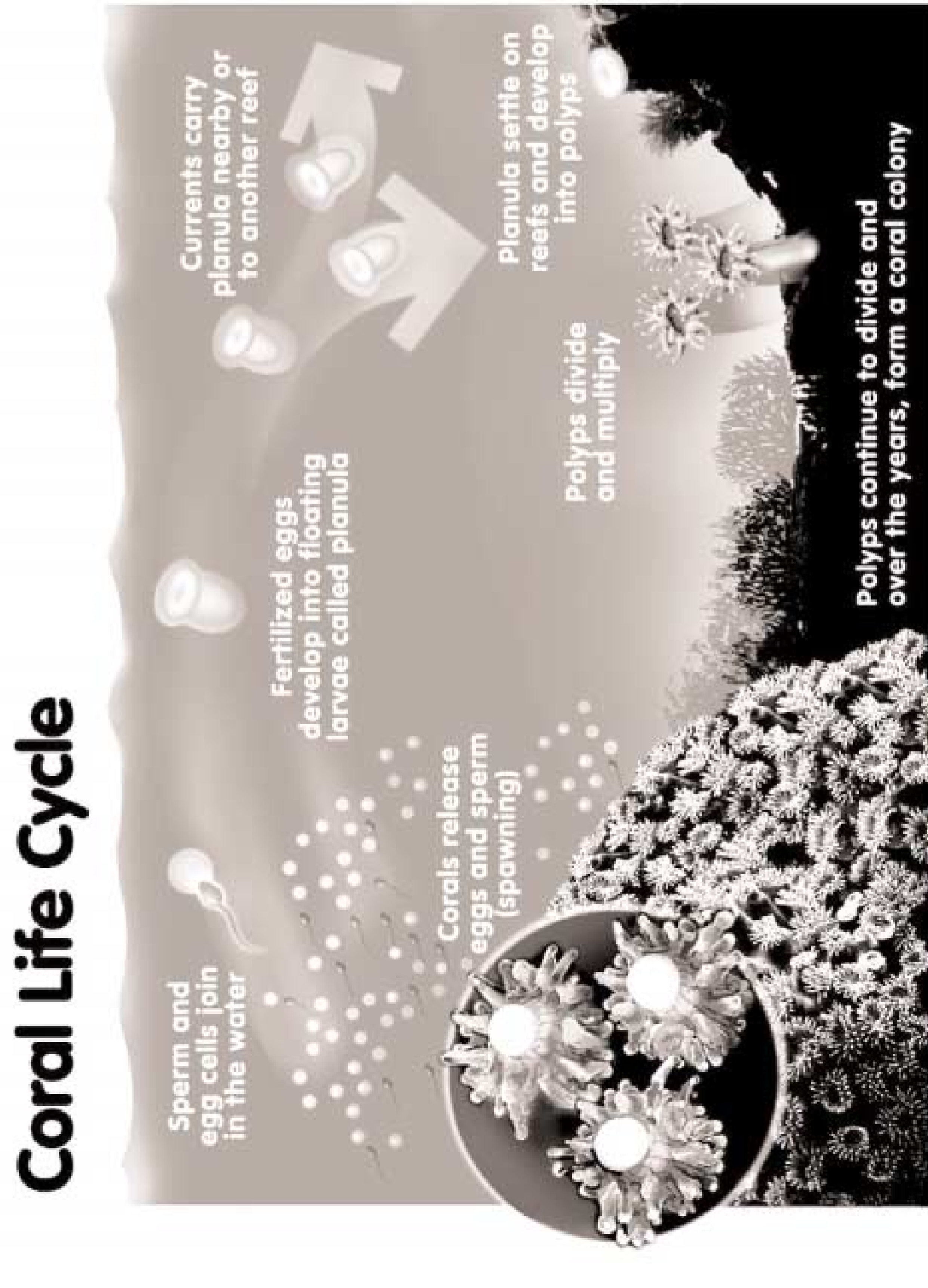


Station 3

Kelp Forest image from *Waves, Wetlands, and Watersheds: California Coastal Commission Science Activity Guide*, 2003. California Coastal Commission, www.coastforyou.org

Station 3

Station 4



Coral Life Cycle
Sperm and egg cells join in the water
Corals release eggs and sperm (spawning)
Fertilized eggs develop into floating larvae called planula
Currents carry planula nearby or to another reef
Planula settle on reefs and develop into polyps
Polyps divide and multiply
Polyps continue to divide and over the years, form a coral colony

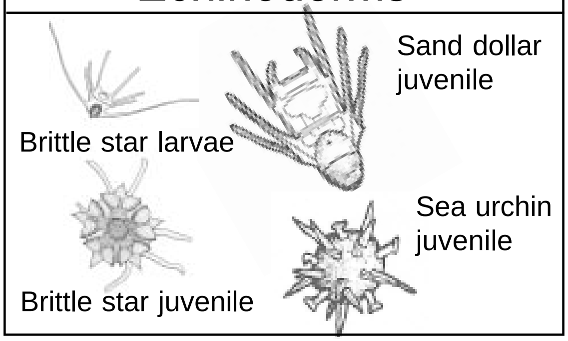
Station 6

PostScriptPicture
plankton cards test for export.p65

Station 6

FOLD

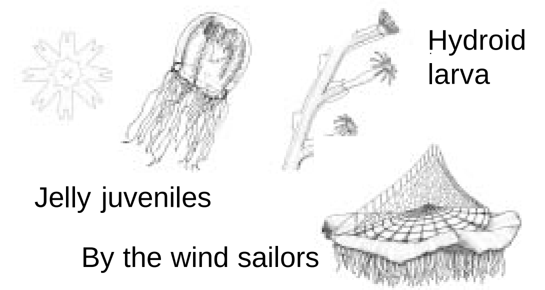
Echinoderms



Echinoderms

- Echinoderms include sea stars, sea urchins, sand dollars, and sea cucumbers. Echinoderm means "spiny skinned."
- Most echinoderms have a larval stage and may be found swimming in the plankton. These larvae change into adults that look very different.
- Some echinoderm species have larvae that do not feed.
- **Most echinoderm larvae and early juveniles eat plankton, including bacteria.**

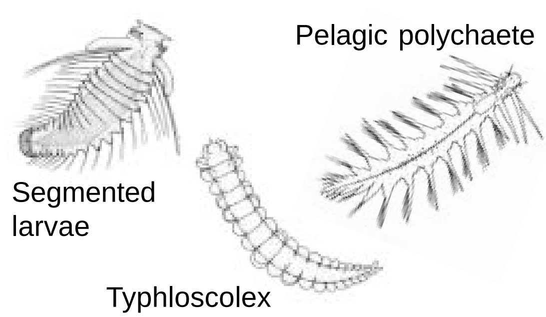
Cnidaria



Cnidaria

- Cnidarians include coral, anemones, and jellies.
- Coral is attached to the bottom, but its larvae is plankton.
- Whether they are tiny or huge, most jellies remain plankton their entire lives because they are not strong enough to swim against ocean currents.
- Some jellies start out as polyps attached to rocks and only become plankton later in life.
- **Jellies and anemones eat phytoplankton and zooplankton.**

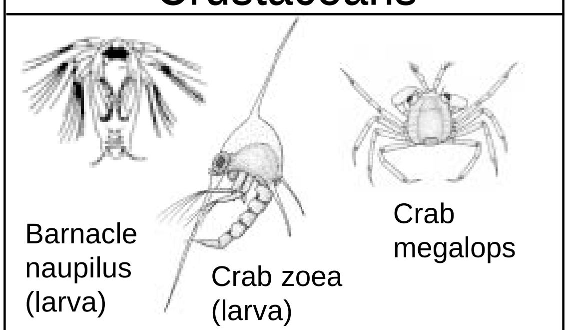
Annelids



Annelids

- Annelids are worms and leeches. Marine leeches attach to fish.
- When a polychaete ("many bristles") worm is bitten in half, it can grow back the missing part.
- Polychaetes use their bristles for swimming and breathing.
- **Annelids eat phytoplankton and zooplankton.**

Crustaceans



Crustaceans

- Crustaceans are "the insects of the sea."
- They are members of the largest of all invertebrate groups, the arthropods.
- Crustaceans include crab, lobster, shrimp, barnacles, krill, and copepods.
- Crustaceans are holoplankton (copepods, krill), and meroplaknton (crab larvae, lobster larvae).
- Larval crustaceans look very different from adults.
- **Crustacean larvae and juveniles eat phytoplankton and smaller zooplankton.**

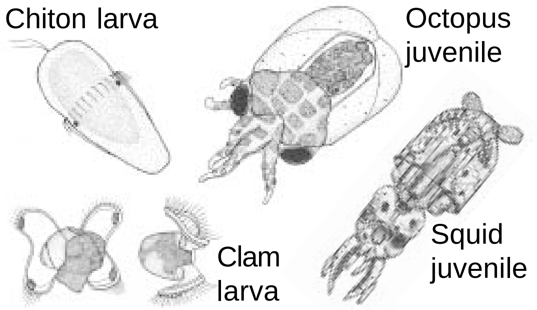
Instructions: *1. Photocopy and fold on center line.*
2. Cut horizontally for double-sided cards.
3. Trim and laminate.

Reference: *A Guide To Marine Coastal Plankton and Marine Invertebrate Larvae, Second Ed.*, by DeBoyd. L.Smith and Kevin. B. Johnson.

Station 6

FOLD

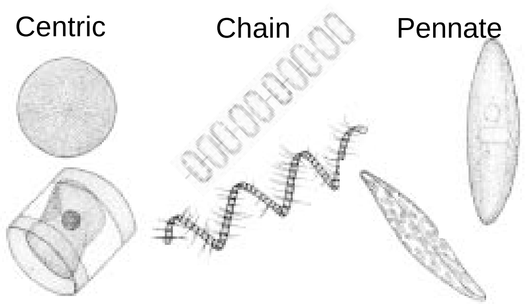
Molluscs



Molluscs

- Molluscs are the second largest of all invertebrate groups; they include snails, limpets and abalone, clams and oysters, squid and octopus.
- Colorful nudibranchs are also molluscs.
- Most shells that people collect on beaches are molluscs.
- **Larval and early juvenile molluscs eat phytoplankton and smaller zooplankton.**

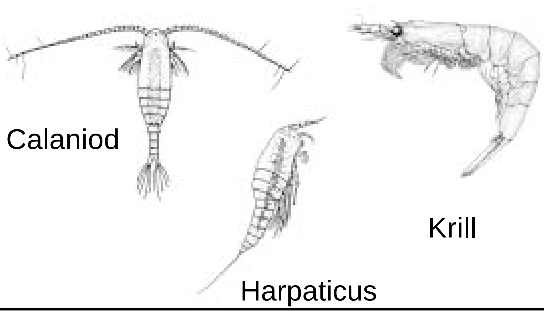
Diatoms



Diatoms

- Diatoms are plant plankton that form an outer shell made of silica, a glass-like material.
- Scientists use sunken diatom fossils to find out what Earth's weather was like millions of years ago.
- Centric diatoms have circular, triangular, or pill-box shapes.
- Chain diatoms can form long chains in the water.
- Pennate diatoms are boat-shaped or needle-shaped.
- Zooplankton and filter feeders eat diatoms.
- **Diatoms get their energy from the sun.**

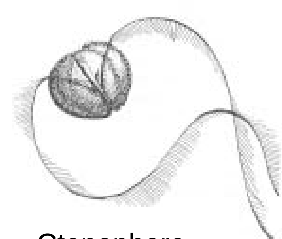
Copepods



Copepods

- Copepods are crustaceans, related to shrimp, lobsters, and crabs.
- Copepod means "oar-footed."
- There are more copepods than any other life form on Earth—more than people, ants, mosquitos, or fleas!
- Copepods have only one eye, which they use to sense light or dark. They move toward light and away from dark.
- **Krill are copepods. Filter feeding whales, such as blue and gray whales, eat mostly krill.**

Ctenophore



Ctenophore

- Ctenophores ("comb bearer") or comb jellies, are common names for animals in the Phylum Ctenophora. Though similar, they are not true jellies.
- The name is pronounced with a silent "c", as "teen-o-four."
- Ctenophores have eight rows of cilia, or hairs, which they use to swim by beating their comb plates.
- Most ctenophores are clear and colorless.
- **Comb jellies lack stinging cells but have sticky tentacles to capture their prey, zooplankton.**

Instructions: *1. Photocopy and fold on center line.*
2. Cut horizontally for double-sided cards.
3. Trim and laminate.

Reference: *A Guide To Marine Coastal Plankton and Marine Invertebrate Larvae, Second Ed.*, by DeBoyd. L.Smith and Kevin. B. Johnson. Copyright 1996 by Deboyd. L. Smith and Kevin B. Johnson. Reprinted by permission of Kendall/Hunt Publishing Company.

Watersheds of the Monterey Bay National Marine Sanctuary

11 major watersheds drain into the Monterey Bay National Marine Sanctuary:

1. San Francisco Bay Estuary
2. North Coastal
3. Gazos/Scott Creeks
4. San Lorenzo River
5. Pajaro River
6. Alisal Canal
7. Elkhorn Slough
8. Marina/Pacific Grove
9. Carmel River
10. Salinas River
11. South Coastal